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Edited by
Chee-Kit Looi,
Joseph Polman,
Ulrike Cress, and
Peter Reimann

Transforming Learning, Empowering Learners

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Transforming Learning, Empowering Learners:
The International Conference of the Learning Sciences (ICLS) 2016

Volume 2

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of the Learning Sciences

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Nanyang Technological University,
Singapore

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Preface

The National Institute of Education, Nanyang Technological University of Singapore, is hosting the 12th International Conference of the Learning Sciences (ICLS), 2016, from 20 to 24 June, 2016. The international and interdisciplinary field of the Learning Sciences brings together researchers from the fields of cognitive science, educational research, psychology, computer science, artificial intelligence, information sciences, anthropology, sociology, neurosciences, and other fields to study learning in a wide variety of formal and informal contexts (see www.isls.org). The field emerged in the late 1980s and early 1990s, with the first ICLS held in 1991 at Northwestern University in Evanston, Illinois, USA. Subsequent meetings of ICLS were held again in Evanston, USA (1996), Atlanta, GA, USA (1998), Ann Arbor, MI, USA (2000), Seattle, WA, USA (2002), Santa Monica, CA, USA (2004), Bloomington, IN, USA (2006), Utrecht, the Netherlands (2008), Chicago, IL, USA (2010), Sydney, NSW, Australia (2012), and Boulder, CO, USA (2014). ICLS 2016 is the first time that the conference is being held in Asia.

Submissions for ICLS 2016 were received in November 2015, and then went through a process of peer review. An impressive number of submissions were received (571). The paper review process was very competitive. The overall acceptance rate for submissions was 37%. We accepted 65% of symposium submissions, 31% of full papers, 34% of short papers, and 43% of posters. The program reflects broad geographic representation, with contributions from 31 countries and regions. We are especially grateful to those who performed reviews. 342 experts completed over 1,600 reviews of the submissions. As in recent years, for each symposium, full paper and short paper, we assigned a senior reviewer who examined all reviews and made a recommendation regarding acceptance in the category submitted, acceptance in an alternate category, or rejection. These senior reviewers greatly helped us make the decisions for each submission.

The conference theme of ICLS 2016 is "Transforming Learning, Empowering Learners." It directs our attention to a key commitment of the Learning Sciences: providing an insightful understanding of how people learn. As we trace the genesis of the Learning Sciences, we are reminded of the main goal of this field of research, that is, to gain a deep understanding of the conditions and processes that lead to effective learning, and to use the research findings to redesign learning environments to bring about deep learning. Learning Sciences is concerned with transforming learning and empowering learners.

This long-standing commitment extends our research focus to the design of pedagogical interventions and learning environments to foster among participants a kind of learning that is transformative and empowering. This requires challenging established beliefs about learning, teaching, and the design of learning environments. The theme "Transforming Learning, Empowering Learners" aims at reaffirming the key thrust of Learning Sciences research, discussing advances in the field, and strategizing future directions to enhance our impact on educational practice. ICLS 2016 aims to bring together learning scientists to adjudicate various academic renditions of how people learn, and to institute further inquiry that encourages deep and probing examination of the nexus of instruction and learning, as well as the roles of technology. To address the conference theme, we articulated the following strands:

Deep learning in effective learning environments

The field of Learning Sciences is committed to advancing research for explaining how people learn and what can be done to support deep learning. Towards these goals, different studies have examined learners' prior knowledge and preconceptions, knowledge representation, and knowledge construction. Research provides insights into the underlying cognitive bases of problem-solving, knowledge construction, reasoning, reflection and deep learning. Such understanding is necessary for designing effective learning environments needed to transform and enhance learning. In continuing this tradition of the Learning Sciences, perspectives that demonstrate scholarly depth on cognitive, social, psychological and/or cultural aspects of learning are valued. Relevant topics include learning theories, pedagogies, individual and group learning, learner agency and identity in learning, cognition and instruction, learning in all areas of the curriculum, conceptual change, and scaffolding.

A number of studies in Learning Sciences have paid attention to technology use and its affordances for deep learning. Computer-mediated learning remains key in Learning Sciences as research on new media, e-learning, adaptive and intelligent systems continues to proliferate. The conference program includes work that contributes

to the ongoing dialogues about the use of adaptive systems and intelligent tutoring in innovative learning situations, computer-supported collaborative learning, use of computers for group and distributed cognition, computational models of how people learn, use of computers for assessment in virtual classrooms, and scholarly work on technology use to support learning communities. Sessions on emerging topics like MOOCs, big data, and the relevance of neuroscience should also stimulate thought and debate about the future of the field.

By emphasizing a strand on deep learning in effective learning environments, we hope the community can assess the extent to which educational institutions have shifted towards deep learning in their pedagogical approaches. As a research community, we can question how well the Learning Sciences have contributed to educational practice, and suggest what else can be done to design our social future of learning as we collectively expand our vision of transforming learning.

Digital epistemologies and the situated nature of learning

One key research thrust in Learning Sciences is aimed at understanding the situated nature of learning in diverse sociocultural practices. Empirical accounts of such work serve to extend our knowledge of how people learn by informing us about how young people learn informally in out-of-school practices. Sociocultural studies on situated cognition, the roles of context in cognition, collaborative discourse, self-directed learning in the online world, and participatory culture in cyberspace are topics important to advancing the field of Learning Sciences.

A number of studies have emphasized how young people have challenged our understanding of what is learnt and not learnt in schools, and how schools can appropriately respond to changing digital epistemologies. By digital epistemologies, we are referring to ways of knowing embraced by participants in myriad digital literacy practices. Young people's digital epistemologies and learning in the new media age open vistas on a whole range of complex issues. At this conference, we welcome debates on the roles of out-of-school literacies in school literacies and studies that illuminate how formal and informal learning can be synergized. It is worth rethinking ways of knowing in young people's digital literacy practices, and we hope ICLS 2016 can create the opportunities for rich dialogues that address issues of learner identities, new cultures of learning, and their implications to the design of learning environments as we seek to understand more of how young people take ownership of their learning in and out of school in their digital culture.

Teacher knowledge and professional development

To transform learning, we cannot ignore the critical roles played by teachers in enacting and innovating classroom practices. Traditionally, off-site workshops or courses are linked to programs offered by institutions of higher learning, often associated with the formal granting of a higher degree. While off-site learning experiences provide teachers with opportunities to interact with researchers and explore ideas based on research findings, they are often criticized for being too removed from authentic classroom contexts, thus lacking the transformative power to change classroom practices. Some studies have been conducted on teachers' development of pedagogical content knowledge, and some on meta-strategic knowledge. A number of studies in the Learning Sciences have focused on strategies for teacher professional development and learning, including the use of blogs, problem-based learning, animated classroom stories, immersive virtual reality, and small group reflection. The conference program includes research and discussion on new modes of teacher professional development and learning, and ways to enhance knowledge sharing among teachers, including the investigation of mechanisms that enable knowledge codification, validation, and dissemination of expert teacher knowledge. At ICLS 2016, we hope to engage in dialogues on how Learning Sciences research can further our investigation of ways to bring about changes in teacher beliefs—about epistemology, ontology, and practice—necessary to change classroom practices on a sustainable basis.

Reflexive relations between methods and theories

To realize the goals of "Transforming Learning, Empowering Learners," Learning Sciences researchers have developed new research methodologies and methods. One distinctive example is the development of the design experiment (or design research) methodology. At ICLS 2016, we welcome discussion and sharing of advancements on design research. The design experiment has the distinctive feature of advancing theories that can guide the design of learning activities. It involves theory-informed pedagogical interventions that are both reflective and prospective in nature. It has the dual goal of evaluating how well the theory-informed intervention works and generating ideas for further experiments. Many researchers have also engaged practitioners in the process of design experiment, for example, by involving teachers in the design of classroom interventions. This

method is an approach that can potentially lead to empowerment of practitioners while giving them voice and agency in the research process. From another perspective, it is an approach to develop practitioners' professional learning.

We also welcome experimental studies that analyzed the processes and outcomes of learning in detail. We hope the conference stimulates dialogues on the usefulness of big data and learning analytics. Several studies related to learning analytics highlight evolving lines of inquiry that are of interest to the Learning Sciences, including use of learning analytics for blended learning, learner assessment, new models of learning, and the roles of pedagogy in learning analytics. Our purpose in foregrounding learning analytics in this conference is to instill greater interest in studying how learning analytics can have a greater impact on educational practice, particularly in the area of using technology for assessment.

In these proceedings volumes, you will find a wide variety of perspectives and research findings concerning the above issues and questions, and we hope that you will have insightful and productive conversations during as well as after the conference.

Finally, we express our deepest gratitude to the many people who made the conference possible: the organizing committee, the advisory committee, the program committee, the co-chairs of workshops, doctoral student consortium, early career and mid-career workshops, reviewers, sponsors, volunteers, staff, and all conference presenters and participants. Your contributions make the learning sciences a thriving field, striving to transform learning and empowering learners.

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Chee-Kit Looi, Joseph Polman, Ulrike Cress, and Peter Reimann

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Bringing Computational Thinking Into High School Mathematics and Science Classrooms

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Abstract: Computation is reshaping modern science and mathematics practices, but relatively few students have access to, or take, courses that adequately prepare them for the increasingly technological nature of these fields. Further, students who do study computational topics tend to not reflect the greater student body, with female and minority students being disproportionately underrepresented. To address these issues, we investigate the approach of embedding computational thinking content into required high school mathematics and science coursework. Using data from a 3-year implementation, we present results showing differences in attitudes towards computing by gender, while also finding similar gaps do not correlate with aptitude. Using pre/post measures, we then show female participants expressed improved confidence with computational thinking and interest in STEM careers. Additionally, we report a dosage effect, where participating in more activities resulted in greater learning gains, providing evidence in support of embedding computational thinking enhanced activities across high school curriculum.

Keywords: computational thinking, high school mathematics and science, broadening participation

Introduction

Computation is changing the landscape of modern scientific and mathematical fields. Computational tools, practices, and methods are reshaping the way mathematicians and scientists conduct their work. This is true in research laboratories, in industry, and increasingly, in educational settings as well. Given the growing computational presence across mathematics and science contexts, the question faced by educational institutions is how to prepare learners for the increasingly computational nature of these disciplines. Our answer to this question is to bring computation and computational thinking enhanced activities into existing mathematics and science classrooms. As such, we have pursued a course of research working to integrate computational thinking (CT) into high school mathematics and science contexts through the creation of CT enhanced curricula across four primary STEM subject areas: biology, chemistry, physics and mathematics. Our conceptualization of CT as it relates to mathematics and science takes the form of a taxonomy that delineates a series of specific practices grouped into four, overarching categories: data practices, modeling and simulation practices, computational problem solving practices, and systems thinking practices (Weintrop et al., 2016). In this paper, we provide data showing the positive effects of distributing CT across the curriculum and across classrooms, as opposed to limiting exposure to a single classroom or a single unit. These effects include improved attitudes towards, and confidence in, computing as well as increased interest in pursuing careers in STEM disciplines. Additionally, based on data from the final year of a three-year study, we report a dosage effect; showing that students who encountered more CT enhanced activities performed better on posttests designed to measure learners' CT abilities. Collectively, these findings lend support to the effectiveness of embedding CT in existing mathematics and science classrooms as an approach to improving attitudes towards the field, engaging diverse and historically underrepresented populations in computing, and preparing students for the computational futures that await them regardless of the professions they choose to pursue.

Practical motivation

A primary motivation for introducing CT practices into science and mathematics classrooms is in response to the increasingly computational nature of the disciplines as they are practiced in the professional world (Education Policy Committee, 2014; Foster, 2006; Malyn-Smith & Lee, 2012; Weintrop et al., 2016). Computation is now an indispensable component of STEM disciplines (Henderson, Cortina, & Wing, 2007). This rise in importance of CT and its constituent skills and practices has been recognized both by those creating standards for mathematics and science classrooms (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010; NGSS Lead States, 2013) as well as by computer science education organizations (ACM/IEEE-CS Joint Task Force on Computing Curricula, 2013). Bringing computational tools and practices into mathematics

and science classrooms gives learners a more realistic view of what STEM fields are and better prepares students for STEM careers (Augustine, 2005; Gardner, 1983).

Preparing students for the modern STEM landscape is not the only reason to bring CT into STEM classrooms. From a pedagogical perspective, the thoughtful use of computational tools and skillsets can deepen learning of STEM content (Guzdial, 1994; National Research Council, 2011; Repenning, Webb, & Ioannidou, 2010; Sengupta et al., 2013; Wilensky, Brady, & Horn, 2014; Wilensky & Reisman, 2006). The reverse is also true – namely, that science and mathematics provides a meaningful context (and set of problems) within which CT can be applied (Hambrusch et al., 2009; Jona et al., 2014; Lin et al., 2009; Wilensky et al., 2014). This differs markedly from teaching CT as part of a standalone course where the assignments tend to be divorced from real-world problems and applications. This reciprocal relationship—using computation to enrich STEM learning and using STEM to enrich computational learning—is at the heart of our motivation to bring CT and STEM together.

A third motivation for bringing CT into STEM classrooms is to reach the widest possible audience and address the longstanding issues of underrepresentation of women and minorities in computational fields. Despite numerous ongoing local, regional, and national campaigns targeting women and underrepresented minorities, the numbers continue to drop in STEM (National Science Board, 2012) and computer science (Klawe and Levenson, 1995) enrollments. Among the reasons for these trends, researchers have identified a lack of interest and confidence (Margolis, Fisher, & Miller, 2000), limited visibility of positive role models (Townsend, 2002), and lack of positive experiences with both computer science and in STEM fields more broadly (AAUW, 1994; Miliszewska, Barker, Henderson, & Sztendur, 2006). Currently, only a fraction of high school students have the opportunity to take a computer science course due to a lack of qualified teachers, inadequate facilities, or a lack of student interest. Embedding CT activities in STEM coursework directly addresses the issue of students self-selecting into (or out of) computational learning experiences. It also avoids practical issues of fitting new classes into overcrowded schedules and finding teachers to teach them. Collectively, these aspects of the relationship between CT and STEM, paired with the ability to reach diverse audiences and work within existing educational infrastructure, makes the embedded CT design a potentially powerful and effective approach to bring CT to diverse learners.

Theoretical perspective

Efforts to incorporate computational thinking into high school curricula have been hampered by shifting and underspecified definitions of what constitutes CT skills and practices. Our definition of CT is framed within two core theoretical constructs: 1) Wilensky and Papert's concept of restructuration (Wilensky & Papert, 2010) and 2) diSessa's framework for computational literacy (diSessa, 2000). Wilensky and Papert's work defines a structuration as the knowledge content of a domain as a function of the representational infrastructure used to express it. A restructuration is a shift in representational infrastructure in a domain, which inevitably changes the practices in that domain and the ways we teach and learn the domain. For example, a major restructuration of arithmetic took place around the turn of the first millennium with the shift from Roman to Hindu Arabic numerals. The place value construct embedded in Hindu-Arabic numerals radically reshaped what was possible to do with numbers and shifted, for example, multiplication and division, from an activity that only small number of highly trained specialists were capable of, to a nearly universal practice. We believe that computational representations are already beginning to have a major restructurational effect on STEM disciplines (e.g. Abelson & DiSessa, 1986; Blikstein & Wilensky, 2009; Noss & Hoyles, 1996; Sengupta & Wilensky, 2009; Wilensky & Reisman, 2006) and that through embedding CT practices in mathematics and science contexts we can prepare learners for this shift.

diSessa notes that for a representational infrastructure to become universal it has to specialize to several social niches. So for example, print literacy specializes to the niches of poetry and romance novels among many others. Similarly, we see computational representations as specializing to a variety of niches, each with its own conventions (in contrast to a single monolithic set of practices). The unifying theme amongst all our CT activities is exploring the ways we can use computational representations to make significant shifts in the way students learn, think and practice science and mathematics. Thus, we developed a taxonomy (Figure 1) to frame our work that describes and organizes the various 'niches' of computational representations and practices in mathematics and science disciplines (Weintrop et al., 2016). Through the taxonomy, we begin to identify commonalities and patterns across these practices that we can then leverage to design educational activities to grow students' proficiency in, and understanding of, these new computational representations in various STEM disciplines. Building proficiency in these new forms of representations is what we mean by *computational thinking in mathematics and science*.
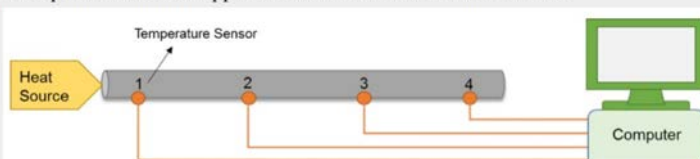
Data Practices	Modeling & Simulation Practices	Computational Problem Solving Practices	Systems Thinking Practices
Collecting Data	Using Computational Models to Understand a Concept	Preparing Problems for Computational Solutions	Investigating a Complex System as a Whole
Creating Data	Using Computational Models to Find and Test Solutions	Programming	Understanding the Relationships within a System
Manipulating Data	Assessing Computational Models	Choosing Effective Computational Tools	Thinking in Levels
Analyzing Data	Designing Computational Models	Assessing Different Approaches/Solutions to a Problem	Communicating Information about a System
Visualizing Data	Constructing Computational Models	Developing Modular Computational Solutions	Defining Systems and Managing Complexity
		Creating Computational Abstractions	
		Troubleshooting and Debugging	

<u>Figure 1</u>. The computational thinking in mathematics and science practices taxonomy.

Methods and data sources

The data we present in this paper were collected as part of a larger, 3-year study investigating the effectiveness of the embedded CT in mathematics and science strategy. Over the course of the project, 58 teachers attended professional development workshops from 38 schools. The data we present are from 11 classrooms in a Midwestern city that participated in the third year of the project. As part of the study, pre/post attitudinal and CT skills assessments were administered along with classroom observations and teacher interviews. The attitudinal surveys were modeled after other similar efforts to measure student attitudes in STEM and computer science contexts (Adams et al., 2006; Dorn & Elliott Tew, 2015). The pre/post skills assessments were designed as part of the larger project and were designed to assess students' abilities to employ CT practices, as opposed to content knowledge of a given scientific or mathematical domain (Weintrop et al., 2014). The assessment are hosted online and ask students to use various computational tools (including interactive data visualizations, computational models and simulations, and dynamic data management widgets) to answer open ended and multiple choice questions relating to the four CT in mathematics and science categories shown in Figure 1.

<u>Figure 2.</u> A sample multiple choice question from a CT skills assessments.

The CT-enhanced lesson plans that were taught as part of this study were designed by members of the research team in collaboration with graduate students working in STEM fields as part of an educational outreach program. The lessons were designed in conjunction with in-service mathematics and science teachers and later taught in their high school classrooms. An important part of this outreach program is for graduate students to bring their own research into high school classrooms, both showing high school students what cutting edge research looks like and to bring diverse, practicing scientists into the classroom to confront the misconception that all scientists are old, Caucasian men wearing lab coats. The graduate students and teachers who contributed lesson plans were vetted through professional development training on what CT means in mathematics and scientific contexts. Lessons were created for high school mathematics, biology, chemistry, and physics classes and included subjects as diverse as US census data, radioactivity, black holes, and video games. Lessons usually lasted two or three class periods and, when possible, used the same computational tools that the scientists themselves use in their work. For example, one lesson plan called DNA sequencing had students study and apply the shotgun

algorithm that was used to sequence the human genome, and then introduces them to BLAST, an online search tool that scientists use to explore the conservation of, and differences in, DNA sequences of different organisms. With this activity, we bring together scientific content, CT (in the form of algorithms and working with data), as well as having students use modern computational tools, bringing authenticity to the activity. A longer description of some of the activities in this study and how the incorporate CT can be found in (Weintrop et al, 2016).

The attitudinal data we present are drawn from surveys that were administered to students in participating classrooms at the beginning and the end of the school year. A total of 704 attitudinal surveys were completed (475 pre and 229 post) with 49.7% of the surveys being filled out by female students. The survey primarily used a 5-point Likert scale and asked students to respond to statements such as "I feel comfortable working with computers" and "I am interested in pursuing a career in engineering." For the CT skills assessment results, a total of 1,022 assessments were completed by 549 students during the 2013-2014 school year. In particular, as we are interested in student trajectory over the course of the year, we focus on the 152 students who took both pre and post tests along with additional assessments during the year, providing a timeline of students' progress over the course of the year.

Results

This section presents findings from both the attitudinal and CT skills assessments conducted as part of this study. In the discussion that follows, we bring these two sets of findings together and reflect on the strategy of embedding CT in mathematics and science that we are investigating.

Attitudinal outcomes

One of our motivations for embedding CT in STEM is to address issues of students self-selecting into or out of elective computer science courses. As a result of our approach, all students enrolled in conventional science and mathematics classes are exposed to CT, thus addressing issues of low numbers of female and minority students taking computer science. Of the 549 students who took an assessment, 49% (271) self-identified as Hispanic, 37% (203) as African American, 15% (83) as white, and 10% (53) as Asian. Of this same sample, 52% were male while 48% were female. These breakdowns are representative of the larger student populations of the schools where these studies took place. The diversity of students taking our assessments and the equality with respect to the gender of students provides evidence that the approach of bringing CT into STEM classes is an effective way to introduce a broad and diverse set of students to CT.

Comparing the responses given on the pre survey between male and female students, we see disparities that match those reported in other studies on gender and STEM and computer science fields (Dryburgh, 2000; Stake & Nickens, 2005). Female students were significantly less interested in the STEM fields, felt CT was less important, and reported being less comfortable with computers than their male counterparts. When asked about interests in possible future professions, female students were significantly less interested in careers in computational sciences, engineering, mathematics, and computer science. Finally, female students were less confident in all 20 questions pertaining to CT in mathematics and scientific contexts. A portion of these results can be seen in Table 1.

Table 1. Average responses given on a 5-point Likert scale for questions on the pre-attitudinal survey.

Statement	Avg. Female Response	Avg. Male Response	T-Statistic
I think being a scientist is a possible career for me.	2.760	3.102	$t(474) = 3.099$, $p < .002$
I think being a mathematician is a possible career for me.	2.502	2.911	$t(474) = 3.717$, $p < .000$
I am interested in a career in engineering	1.747	2.711	$t(474) = 10.96$, $p < .000$
I am interested in a career in mathematics	1.755	2.077	$t(474) = 3.617$, $p < .000$
I am interested in a career in computer science	1.581	2.301	$t(474) = 8.326$, $p < .000$
Generally, I feel comfortable using computational tools.	3.297	3.610	$t(474) = 3.850$, $p < .000$
Generally, I feel comfortable working with computers.	3.799	4.130	$t(474) = 3.976$, $p < .000$
I am used to using computational tools.	3.079	3.463	$t(474) = 4.298$, $p < .000$
I am interested in learning more about computers.	3.188	3.715	$t(474) = 5.675$, $p < .000$
Computational thinking comes naturally to me.	2.913	3.260	$t(474) = 4.739$, $p < .000$

At the end of the school year, the attitudinal survey was re-administered to see if students' perceptions of and attitudes towards CT changed after being exposed to our CT in STEM activities. Responses in the post-test show significant gains on questions relating to interest in pursing careers in science t(349) = 2.018, p < . 05, enjoyment related to using computational tools for schoolwork t(439) = 2.905, p < .05 and the learning benefits of doing so t(349)=2.531, p < .01. Most importantly, female students showed positive gains on 19 of the 20 questions pertaining to confidence in CT in STEM questions. This shift highlights the effectiveness of CT learning experiences situated within STEM for female students.

Skills assessment outcomes

A preliminary analysis of student responses shows no significant difference in performance between students based on gender. Looking at the subset of responses to our General CT in STEM skills assessment set that can be automatically scored, we see that the 161 females had an average score of 2.21 out of 5, while the 192 male students had an average score of 2.27 out of 5, a difference that is not statistically significant t(352) = .377, p = .706. This suggests at the outset of the year, there was no significant difference in CT aptitude by gender, which is especially interesting when taken together with the findings from the previous section showing that confidence differed significantly by gender.

When we look at how students perform on the post assessment compared to the pre assessment, we find no significant difference in the scores. These results were unexpected based on expectations from studies showing repeated encounters with learning technologies improving student comfort level and competencies (Delen & Bulut, 2011) and based on teacher feedback on student engagement and content learning from the CT activities in early pilot studies. As part of our program, we conduct post-implementation surveys, interviews and monitoring. Upon closer analysis, we realized that many of the participating teachers had not taught the minimum three required CT lessons in their courses that were expected as part of the program requirements and teaching agreement. Instead, many teachers taught only a single CT-enhanced lesson in their classrooms. Given this fact, it is less surprising that students did not have a lasting improvement over the course of the year from the single encounter with the practices we were assessing. The silver lining of this situation is that it gave us the ability to investigate the effects of repeated exposure to CT lessons. While the reasons for the lack of compliance varied across teachers and partner schools, and included various justifications and roadblocks ranging from personal to institutional, they served as a representative survey of challenges teachers face when incorporating computing resources into classes that historically have not relied on such technologies.

As we are investigating a whole school model where students are exposed to CT in difference classes and applied in multiple content areas, we are particularly interested in understanding how student who received multiple exposures to CT lessons performed. To examine the possible benefits of multiple exposures to CT in mathematics and science practices over the course of the school year, we look at student pre/post test gains broken down by the number of CT enhanced lessons each student encountered. Table 2 shows the results of this analysis. Students who were exposed to only a single CT event (1) regressed over the course of the year, showing no improvement; while students who were exposed to two CT lessons over the course of the year showed a small increase in their performance, but not at a significant level. In contrast to the first two categories, students who participated in three CT events showed positive gains on our CT in mathematics and science assessments. These findings suggest that the more CT enhanced lessons a student participated in, the larger the student gains between the pretest and posttest.

Table 2: Average student score by number of assessment events taken before the posttest. "1 CT Event" indicates that the student only took the pretest and the posttest with no other assessments.

	1 CT Lesson (N = 50)	2 CT Lessons (N = 24)	3 CT Lessons (N = 77)
Pretest	4.60	5.17	4.87
Posttest	3.78	5.21	5.12
Gain	-0.82	0.04	0.25

To validate this preliminary analysis, we ran a 2-way ANOVA with sex and number of events as independent variables. There was a significant main effect of event number with no interaction for posttest score ($p = 0.000$). There was also a marginally significant main effect of event number for gain (pretest / posttest difference) ($p = 0.066$). Bonferroni post-hoc tests revealed that students with two or three events performed significantly better on the posttest than students with one event ($p < 0.01$). However, for gains, only students with three events were marginally significantly better than students with one event ($p = 0.075$).

There are a number of potential explanations for this outcome. One possible way to explain this dosage effect is a time-on-task outcome. Students who spent longer working on CT enhanced mathematics and science activities performed better on the end-of-the-year post assessments. While this is a very plausible explanation and we would be happy with this outcome, the data suggests that there is more going on than just exposure, as the one and two CT event students show no significant gains. A second possible explanation is that the improved performance is not only due to seeing the material more frequently, but also due to being exposed to varied contexts in which the material is presented. For example, in a year-long physics course, learning and applying CT practices in lessons about electricity, projectile motion, and conservation of energy, might better support learners in developing deeper intuitions and a more flexible understanding of the widely applicable CT practices included in the lessons. Taken a step further, by having students engage with CT practices across both mathematics and science courses, and year-after-year, students' computational thinking abilities may further improve. The analysis of our 3rd year of this study provides positive indications of these hypotheses and we are currently designing a follow-up study that will give us the ability to more precisely study the impact of the embedded CT in mathematics and science approach, with the goal of more clearly being able to attribute these learning gains to the synergy of exposure across different STEM subject areas.

Discussion

With this work, we explore one possible strategy for introducing students to CT through the design of CT enhance activities designed to fit within existing mathematics and science classrooms. This approach seeks to bring CT to wide audiences while at the same time putting in-service teachers in positions to be successful by situating new CT concepts alongside familiar content. To date, this approach has been successful on both of those two fronts. As we show above, embedding CT in required classes enables us to reach all students, directly confronting issues of students self selecting into (or out of) computing learning opportunities. At the same time, the reaction from teachers to this project has been especially positive due to its timing in relation to the adoption of the Next Generation Science Standards, which includes CT as one of eight central scientific practices.

One of the more important findings from this work is the replication of previous findings that show females, on average, having lower confidence with respect to CT, paired with the finding that females show no difference in aptitude. The fact that female students at the start of the year were less confident with respect to computational practices as well as less interested in pursuing careers in computational fields speaks to the need to devise low-barrier entry points into computational learning experiences. This underscores the importance of bringing CT, and computational learning opportunities more broadly, into contexts where all students are present. Our approach of integrating CT with mandatory coursework is one such approach that is yielding positive results with respect to engaging all students in computational learning opportunities. Similarly, the results showing female students have increased confidence with respect to CT and a growth in interest in various computing and STEM careers shows this approach can be successful at cultivating a positive computational and scientific identity.

A second important outcome from this work is finding a dosage effect among students who had multiple exposures to CT enhanced STEM activities. While this could potentially be explained as time-on-task finding (i.e. students spending longer on a topic yield better results), we find the explanation that grounding CT learning experiences in diverse contexts across mathematic and scientific fields to be more compelling. Teasing apart exactly how much of the dosage effect gains can be accounted for by these two explanations is work we intend on pursuing in the future. Computational thinking as a set of practices is not bound to a specific content area, therefore, by having students employ these practices to various types of problems and in diverse content areas, we can reinforce the broad applicability of these skills while both providing students concrete contexts to employ them. This also provides opportunities for teachers to lead discussions and prompt for student reflection about the relationships between CT practices and the contexts in which they can be applied. Encountering multiple CT activities and repeated exposure to CT practices and tools not only reinforces the validity and broad utility of the computational strategies used by modern STEM professionals, but also provides learners with opportunities to become more comfortable and familiar with the tools themselves. Furthermore, our findings suggest that repeated exposure to CT activities is an effective instructional strategy for reinforcing student computational problem solving practices.

Bringing CT into high school classrooms not only provides an effective strategy for introducing diverse populations of learners to important 21st century skills, it also shifts perceptions of what it means to participate in modern mathematics and scientific endeavors. Showing that computation is not just a skillset reserved for those who seek to pursue computer science gives learners a more accurate view of what it means to practice contemporary mathematics and science. Furthermore, in showing the diverse applicability of both CT and computational tools, we can begin to shift how students view computing and how and when computation can be leveraged in pursuit of various goals. We are currently looking to extend the work we present here towards this

goal by shifting from STEM to STEAM and looking at ways to bring computing into arts and humanities classes in the same way we have brought it into mathematics and science contexts. In broadening our approach in this direction, we seek to further demonstrate to students the diverse applicability of CT and show how professionals across a very diverse set of fields utilize computing in their work.

Conclusion

As computational methodologies, tools, and practices continue to drive scientific and mathematical discovery, it is becoming increasingly important for learners to understand how to interpret, and build on, findings that rely on such technologies. This is important not only for those students interested in pursuing careers in mathematics or scientific fields, but for all learners in order to participate in society as scientifically and mathematically, literate citizens. Over the last three years, we have been pursuing an approach to introduce high school learners to these critical computational thinking practices by designing CT enhanced lessons that fit within existing mathematics and science curricula. With this work, we show that this approach is effective at reaching diverse audiences and being easily adopted by in-service teachers. Further, we present data that reveals a dosage effect, showing that the more CT in mathematics and science activities learners are exposed to, the better they perform on our CT practices assessment. Our findings suggest that creating more activities, and finding more ways to enhance existing lesson plans with computational thinking practices, will further improve learners CT in mathematics and science abilities. Our hope is that through taking this approach, we can better prepare today's students for the computational future that await them.

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Acknowledgments

Making Sense of Making Waves: Co-constructing Knowledge and Group Understanding Without Conceptual Convergence

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Abstract: In this paper we argue that collaborative learning doesn't necessarily have to culminate in convergent conceptual change in order to be a success—that divergent perspectives can maintain tensions that are productive for learning even if they don't get reconciled. We analyze the individual *perspectival understandings* demonstrated by students during and after a collaborative task, and argue that this lens provides mechanisms for showing how collaboration can be productive even in the absence of convergence. We discuss some implications for theories of group understanding, and designing face-to-face CSCL environments and activities.

Introduction

Computer-supported collaborative learning environments are becoming increasingly common in both formal and informal educational contexts. In order to effectively design support student learning in these environments, we must understand the interactional processes by which the group as a whole constructs knowledge, as well as how engagement in these processes relates to individual learning. A significant theme in research on this relationship is the interplay between divergence of ideas between individuals, and convergence of the group's understanding (Teasley et al. 2008; Roschelle, 1992). Students may develop divergent ideas, but due to the nature of the collaborative task need to establish and maintain intersubjectivity (Suthers, 2006), a shared system of meaning (Stahl, 2006), common ground (Clark & Brennan, 1991) or a joint conception of the problem (Teasley & Roschelle, 1993) in order to make progress as a group. However, it's not clear whether the divergences that lead to efforts to maintain collective interpretations are breakdowns in local, shared systems of meaning related to the tools and task at hand, or dissimilarities or disagreement in individual participants' conceptual understandings of their activity. Likewise, it is unclear to what extent we should expect individual conceptual understandings to converge in collaboration, or to what extent convergence of conceptual understandings is beneficial either for collaboration or for individual learning.

Convergence is often operationalized in terms of *similarity* between individual mental models (Chi, Siler & Jeong, 2004) or representations of the problem (Roschelle, 1992), or *sharedness* as in knowledge agreed upon or held in common by participants (Jeong and Chi, 2007). In addition to being an outcome, convergence can be also thought of as a *process* of moving toward increasing similarity or sharedness of individual knowledge. An understanding of the role of convergence in relating individual to group-level learning during collaboration has theoretical as well as practical importance—in particular, notions of social or group cognition often rely on these same concepts of similarity or sharedness of meaning, knowledge or understandings of individuals. Without some degree of similarity or sharedness of individual understandings, is it still sensible to say *a group understands*? And for the practical project of designing effective collaborative learning environments, should we include features designed particularly to promote conceptual convergence (and what might these look like)? The aim of this paper is to trace the individual conceptual understandings evidenced in collaborative discourse, and to ask in what ways they may converge or diverge in interaction as students co-construct knowledge. We focus on conceptual discussion during and after a shared task in which a group is asked to produce conceptual explanations.

Theoretical framework

As we are interested in the development of individual conceptual understandings in collaboration, we want a way of characterizing individual conceptual understandings and differences between them, as well as a mechanism for how these evolve in interaction. Greeno and van de Sande (2007) posit that all understandings are *perspectival*. They define a perspectival understanding to be "a cognitive arrangement of entities and some of their properties, organized in relation to each other, with a point of view" (p. 14). Such a conceptual organization may foreground some elements or relations as more important than others. Learning, in this view, is an increased skill in constructing perspectival understandings. A perspective can be constructed by applying a previously learned organizing schema—and if no schema exits, one is constructed through a process of "constraint satisfaction," where the constraints on the use of concepts in constructing perspectives *define* the conception. One aspect of learning then is becoming attuned to the constraints and affordances of particular concepts for constructing appropriate perspectives.

Van de Sande and Greeno (2012) argue that this conceptual organization is a component of the participants' broader *framing* of their activity. They identify three types of framing: *positional* framing describes the individuals' understandings of each other in relation to their activity; *epistemological* framing refers to their understanding of what sorts of knowledge or information are valuable or relevant to their task; *conceptual* framing describes the participants' perspectival organizations of information. Sufficiently aligned framings are thought to be a prerequisite for developing mutual understanding. They propose a process of *constructive listening,* in which a *source* communicates some information relating to constructing a framing, and *listeners* attempt to construct the framing communicated by the speaker. When doing so, the listeners attend to whether the perspective offered satisfies constraints of the concepts being organized. The listeners may adopt the new perspective or modify their existing perspectives to more closely align with the speaker's. In this way, perspectives of individuals can align over time.

Methods

Context and setting

The PHoTOnICs project at UC Davis is a design-based research project with the aim of investigating these social and individual intersections of science learning through design of novel collaborative activities for technology-enhanced, group-based Physics classrooms. Our research setting is a "studio physics" course at UC Davis which aims to keep students engaged in high-level conceptual reasoning. Two aspects of the course serve that goal: small group work for 5 hours/week, and material organized around a small set of physics models. Our project aims to investigate the relationship between the social and technical setting to the development of understandings of those central conceptual physics models. The design presented in this paper focuses on the "mechanical wave" model introduced in the first week of the course.

Learning environment design

The learning environment presented here is designed to support groups of undergraduate physics students in making sense of the physics of mechanical waves. Our design is intended to encourage student interactions around concepts related to mechanical waves and wave motion-- specifically, the concepts of phase, relative phase and phase intervals, and how these relate to observable aspects of wave phenomena such as wavelength and wave direction. Our approach is to design a collaborative "wave-building" task, in which students must coordinate the phases of individually-controlled oscillators to together produce a travelling wave. Performing this coordination will likely require students to collectively take up and make use of these important concepts.

Technology

Each student is given an iPad Air running an interactive simulation of many independent mass-spring oscillators set at equal intervals along the horizontal axis. The oscillators' vertical motion is animated on each iPad when the student pushes a "play" button; the oscillators are returned to their initial positions when the student stops the simulation with a "pause" button. The initial phase of each oscillator, and thus its initial position and direction, can be adjusted using an interactive "unit circle" tool. When used in the networked mode, each iPad connects to a local server that assigns each student in a group control over a subset of the oscillators. When one student makes changes to the position or direction of one of his or her oscillators, the app messages the server, which then communicates those changes to the rest of the group. When each student reruns the simulation on her own device, the initial oscillator positions are updated. When the students set the initial phases of the oscillators at regular intervals, the oscillators will together form a travelling wave, the wavelength depending on the phase interval between adjacent oscillators, and the direction of the wave determined by whether the phases are increasing or decreasing as you move along x-axis.

Analysis

Episode selection

Students were given worksheets with task directions. The task progression was to: use the app to 1) build a wave with a wavelength of 16 units, 2) build a wave with a wavelength of 8 units, and 3) build a wave with a wavelength of 8 units, but moving in the opposite direction. At intervals the researcher approached the group and a series of conceptual questions—how they built their wave, how they knew what direction it was going, and how they would modify their strategy to reverse their wave direction. Our analysis focuses on conceptual talk after the students have completed their first wave-building task. The researcher asks the group questions about how they built their wave (to explain their strategy), about the wave they had built (how they knew what direction the wave was going in), and then lastly, how they would modify their strategy to build a wave going in the opposite direction.

Analytic approach

The goals of our analysis are to uncover the ways in which students evidence their own perspectival understandings. As such enactments involve verbal utterances, gesture, body language, gaze and interactions with materials, we employed interaction analysis (Jordan & Henderson, 1995), in which repeat viewings of the selected episode allowed us to make sense of the interaction at both the "macro" and "micro" interactional levels. We first transcribed the episode fully, additionally annotating hand movements used in communication. Within the video segment and using the transcript, we then identified for further analysis three episodes in which students work to construct a perspective appropriate for a given task.

Results

Episode 1: How did you build your wave?

The group's first attempt to build a wave was to set each point to be at either a maximum or minimum. When they saw the resulting wave they decided to set their points "high, middle, low." Their "middle" points had to be set to be moving in the right direction, and one student, Bryan, did this coordinating work, telling each student in turn which position and direction to set. The class TA interrupted this work, and gave them instructions to build a wave with a wavelength of 16 units. He explained that they should "divide up the unit circle into 16," writing an expression on the group's chalkboard "2*Pi*x/16" as justification. When they were (almost) done building their 16-unit wave, the first author approached the group:

Lisa:	So, how did you make this? What was your strategy for making this?
Corrina:	Uh, step by step,
Bryan:	We used that equation <<points at board>>.
Corrina:	<<points at board>> you had to divide the unit circle up like into <<motions around unit circle>> [inaudible]
Bryan:	We divided it into sixteen… and then realized that there's way more than sixteen columns.

Lisa asks the students what their strategy was for making the wave. B and C respond in turns, each pointing at the equation on the board, and indicating that they had divided up the unit circle. It thus appears that they share a perspective on their strategy, as offered by their TA, that foregrounds the formula written on the board, and its relation to "dividing up" the unit circle. However, C's "step by step" and her subsequent gesture *around* the unit circle suggest that she views their strategy as setting points in a *progression* around the unit circle. B, on the other hand, seems to instead foreground the number of divisions of the unit circle (and continues to throughout later episodes). Lisa leaves the table and the group finishes setting the last few points of their wave.

Soon after, C asks to the group, "So in the equation… what would these points be?" In attempting to make sense of what the group has done, C is suggesting a perspective foregrounding the wave equation, and asking to locate the points along the unit circle from within that perspective. It is likely that such a mathematical perspective is favored as normative in the students' epistemological framing of their activity, possibly because they had been exposed to this equation in the lecture preceding the discussion section. D then suggests that the points are the "phase shift." C clarifies which part of the equation she means— the total phase, or the phase constant. When D repeats that it is the "shift," C asks whether she means "the little phi," (the standard symbolic representation of "phase constant") and D affirms. C and D identify the points the group had laid out around the unit circle with a concept represented in the wave equation, and referred to alternatively as "phase shift," "phase constant" and "the little phi."

Episode 2: How do you know the wave is moving left?

Lisa then asks the students which direction their wave was moving (it was toward the left), and then to explain more precisely how they were able to determine that. A satisfactory explanation requires constructing a perspectival organization of concepts that allows information about one concept to imply information about wave direction. The students struggle here, at first, to construct such a perspective. C first attempts to construct a perspective foregrounding the motion of the *body* of the wave. B's next utterance ("Well I would just describe it as like the phase shift… between… dammit, I don't know.") is an effort to construct a perspective foregrounding both concepts of "phase shift" and "wave direction," but which fails as he could not find either a direct relation between the two, or a set of additional concepts that would allow him to relate the two indirectly. F then introduces

a perspective foregrounding the wave equation written on the board, particularly a sign in the wave equation, and a deterministic relationship between it and wave direction:

Frankie: So if it's traveling to the left it would be a positive phase shift <<drawing a plus sign in the air followed by a squiggly "term">>, and if it's traveling towards the right it would be a minus <<motion left to right, as in drawing a minus sign>>

Corrina: Yeah.

Bryan: I don't know, I would say in layman's terms is the reason why it's traveling to the left is because the dot to the right … for every dot, the dot to the right dictates what its next motion will be. 'Cause it… when the dot to the right travels up, then the dot to the left also starts traveling up. And when the dot to the right travels down the dot to the left also starts going down. Which indicates that like for each dot like if you were looking at each dot as the beginning of the wave, then that dot would be the source. Cause whatever motion it does, the dot next to it also starts to do that after that. So I guess in like non-scientific terms, I'd say that. Maybe. I don't know.

As evidenced by his gestures, F uses the phrase "phase shift" here as a reference to the term immediately following the sign in the equation-- this is not the "phase shift" they had earlier referred to as "the little phi." C agrees with F, which we interpret as an agreement that the perspective being offered is valid or useful. However, B doesn't respond to F's perspective, and instead offers an alternate conceptual framing foregrounding the motions, and the relationship between the motions of, adjacent oscillators. He suggests that wave direction is determined by the relative motion between neighboring oscillators— whether the right or left dot "follows" the other's motion in time.

Both of the perspectives offered by B and F relate different sets of concepts to the concept of "wave direction." B's perspective connected on-screen elements and behavior (oscillator position, direction, and the spatial and temporal relationships between them), while F's perspective connected the sign in the equation written on the board directly to wave direction. Both perspectives are *valid* in that they position wave direction in relation to some set of concepts in a way that allows wave direction to be determined by knowledge of the other concepts— knowledge of the sign in the wave equation, or the relative motions of neighboring oscillators, would both translate into knowledge of wave direction. Yet at this point, the conversation ended and switched to something off-topic. Our interpretation of this was that the students had difficulty in deciding on an appropriate perspective, as the two suggested were both sufficient for their activity of explaining wave direction, yet were very different and not obviously compatible. After the off-topic conversation, E reminds everyone that he still doesn't know how to explain how they know their wave is moving left:

Ernest: I don't get… I still don't get how you tell, like, what direction it's going/…

Bryan: OK, you said something about the phase shift… you should talk about that, because I'm not sure what you mean by that. Are you talking about like the little phi?

Frankie: I was talking about like the actual equation… how it's like a plus… like before the actual phase shift it's either a plus or minus? <<Pointing at chalkboard>>

Bryan: [[B responds that the phase term is only about *where the wave starts* (the initial phase), demonstrating on the board the difference between a wave with an initial phase constant of +Pi/2 and -Pi/2.]]

Ernest: I thought that was just how it shifted. Like <<gestures "grabbing" a wave and shifting it sideways>>.

Their activity returns here to constructing a perspective appropriate for figuring out "how you tell… what direction it's going." In asking F to re-explain his "phase shift" idea, B positions F as a source, and then asks him if he's talking about "the little phi" term in the wave equation (which they had referred to as "phase shift" in Episode One). F responds using the phrase "actual phase shift," suggesting that the "little phi" was not the "phase shift" he was referring to, and describes the "actual" phase shift as immediately following a "plus or minus." It is not clear whether the other students are aware of this possible breakdown in shared meaning.

When F presents his perspective that the positive/negative sign before the "actual phase shift" in the wave equation *determines* wave direction, B responds that the term is "only about where the wave starts." He goes to the chalkboard, demonstrating on the board the difference between a wave with an initial phase constant of +Pi/2 and -Pi/2. E adds that the term is only about how much the wave is *shifted,* gesturing "grabbing a wave" and translating it in one direction by a discrete amount. In expressing this in response to F's perspectives, B and E are introducing a new constraint of the conception of "phase shift," such that "phase shift" is insufficient to relate wave direction to a term in the equation, because "phase shift" identified in the equation determines wave starting *position*, but not *direction*.

Episode 3: How do you reverse wave direction?

A whole-class discussion, led by the TA, interrupted their conversation. The TA ended the discussion with instructions for each group to reverse their wave's direction. After an unsuccessful first attempt, B then introduced a strategy in which each oscillator should be set to either "follow" or "precede" the oscillator to its right or left, depending on the wave direction. This appears to be a re-application of a schema, previously constructed by B to explain wave direction in Episode 2, to the new problem of *reversing* wave direction. E responds to this perspective with "I see what you mean," suggesting that B had indeed been positioned as a source, and that E was listening constructively and understood the proposed perspective. E continues, "… but I don't know how to explain that using that formula," suggesting a reframing of their wave-building activity foregrounding the formula written by the TA-- possibly because E's epistemological framing of the activity gives preference to a conceptual organization of *mathematical* constructs. B then suggests that the formula is "just for figuring out how many segments we need for the wavelength to work," consistent with his initial foregrounding of the division of the unit circle into "segments."

They then build their wave, this time with a wavelength of 8. B does the coordinating work, addressing each person in turn, and telling them which direction their oscillator should be traveling. He says things like "OK, yours needs to be going up." Meanwhile, E chimed in with instructions such as "in the middle… fourth quadrant." So again in communicating instructions, B is foregrounding oscillator *motions*, while E foregrounds the location of the dot on the unit circle representation. Lisa approaches the group again to ask them how they reversed their wave direction:

Ernest:	I don't know how to do that in terms of the formula <<pointing at board>>… we just made it so that each one went to the like… I don't know how you described it <<gesturing at B>>… we just used the unit circle. <<Gestures smoothly around unit circle>>
Researcher:	OK. So what was different between this time and the last time that you did it? What did you change?
Bryan:	Um. The way that I was thinking about it for this… basically in the old one when it's going to the left, if we think of each dot as the source, the dot to the right dictates what the dot to the left is going to do. So we just switched it so that the dot on the left is going to dictate what the dot on the right is going to do.
Researcher:	OK. And then how did that come out in the strategy that you guys used when you actually built the wave? Like, how did you… what was your— what was your procedure for building the wave?
Ernest:	So we had like the red dot set at zero, then we told the person after to set theirs up at like… at like, before <<gesturing at neighboring points around unit circle>>
Bryan:	We just had to be mindful of which quadrant we were in for the direction. So just make sure if this one's heading down, this one has to follow that one, this one has to follow that one… <<gesturing on wave body, at individual oscillators>>

Again, E expresses concern that the strategy is not framed in terms of "the formula." E is aware of B's different perspective, and understood it, but did not adopt it himself—instead, he applies a perspective foregrounding the *progression* of points around the unit circle. B then presents his "source perspective," and so sees their strategy as setting positions and directions of the oscillators to follow one another in space. E, on the other hand, sees their strategy more closely tied to being before/after on the unit circle. E and B have different

perspectives, E's foregrounding the unit circle and B's foregrounding the individual oscillator motions relative to one another.

After some discussion of how they changed their wavelength from 16 to 8, Lisa asks the group again how they knew their original wave was going left. E responds that "it just looked like it" and B with "it was just the source thing." These different perspectives have different affordances for making conceptual connections to *wave direction*—while E's unit circle-based perspective didn't yet allow him to explain wave direction, B's did. Lisa shows them an interface element designed to connect relative motions on the unit circle to relative motions in space, suggesting to them a reframing that would foreground the relative oscillator motions on the unit circle. C then attempts to construct a perspective connecting the motion of two adjacent dots on the unit circle to wave direction, as well as the sign in the equation:

Corrina:	So we made it shifting to the right right now <<gestures at wave body>>… and these two dots are moving <<gesture on unit circle>>… Wait, But that's weird, because when you put the plus or minus <<points at wave equation on board>>, minus means it's moving to the right, right?
Bryan:	Are you talking about the phase shift thing again?
Corrina:	Yeah, I was going to say…
Brian:	This <<pointing to the sign in the wave equation>> has nothing to do with direction. At all. That is just about the shift.
Corrina:	But it has to do with the shift in the… <<gesturing on unit circle>>
Ernest:	But it has to do with the whole graph shifting left to right <<gesturing "grabbing" a wavelength and shifting it to the right by a discrete amount>>

But B again responds with the constraint that the sign has "nothing to do with direction" but is just "about the shift." C responds by suggesting a reframing in which "shift" should be interpreted as a shift represented *on the unit circle*, between neighboring oscillators. E agrees with B again, elaborating that "it has to do with the whole graph shifting left to right." So again their difficulties in incorporating the concept of "phase shift" to connect the equation to wave direction are due to a constraint that "phase shift" should be represented graphically as a *discrete* shift. B then attempts to construct a perspective still foregrounding his concept of "following," but this time also foregrounding relative motions on the unit circle:

Bryan:	If we just switched, on the unit circle, if we just switched the yellow and blue dots, so that the blue was following the yellow, does that change the direction? Or does that just change…
Corrina:	I think that changes direction…

[[They try it, and see that it works.]]

Bryan:	But what did we do? Like, how do you explain that, we just switched the dots on the unit circle.
Ernest:	How do you explain that mathematically? I have no idea. Let's just ask.

B re-interprets "following" by foregrounding its representation on the unit circle, and applies this new framing to the problem of reversing their wave direction with a new "switching dots" strategy. They see that this strategy works, but agree that it isn't well justified ("how do you explain that?"). E elaborates that it should be explained *mathematically*. After a couple minutes of waiting, B walked to the group's chalkboard and wrote out, separately, two independent terms of the wave equation: the "x term" and the "t term." Looking to his group members for agreement, he began to try to "map" the terms in the equation to elements of the wave simulation (ex: "x is just which segment, right?"). With help primarily from E, he then began to write out a sequence of phases corresponding to the phases of their wave's oscillators, going left to right. After writing a few phases in the sequence, D interrupted him to complete and correct B's written equation, dictating the correct form to him carefully. They then decided that the (now correctly placed) plus/minus term "maps" to wave direction ("and [[the sign]] changes the direction?"), and appear to arrive at a consensus ("alright, we'll go with that then."). Lisa returned to ask the students again what they did to reverse their wave direction:

Bryan:	We said plus or minus in the second part of the equation… to change it.

Researcher:	So what does that mean physically… or what does that mean in the app?
Corrina:	<<gestures direction around unit circle>>
Bryan:	The only thing I can think of is the source thing.
Ernest:	Changing direction around the unit circle <<gesture toward C>>.

Bryan tells Lisa "we said plus or minus in that second part of the equation… to change it." His inclusion of "in that second part" suggests that the group had indeed clarified which term in the equation the sign preceded. Though they appear to have agreed on this perspective ("we said"), when Lisa asked "so what does that mean physically, or what does that mean in the app?" the students again evidenced distinct perspectives in their responses. B responded that the only thing he could think of was "the source thing," while C gestured the direction around the unit circle, and E also said "changing the direction around the unit circle," gesturing toward C. This last connection—that reversing the progression around the unit circle would reverse the wave direction—was a conceptual development that had not been shared at the group level. Likely because C and E had consistently held perspectives foregrounding progressions around the unit circle, they were able to make this connection between the sign in the wave equation and reversing the direction of this progression. However, it appears that because B never saw their strategy as setting a *progression* around the unit circle, but saw their interactions with the unit circle as simply in service of setting *motions* of oscillators to be following/preceding one another, he was unable to make the connection between the mathematical meaning of the plus/minus sign in the wave equation, and the wave-building strategy as he understood it.

Discussion

Across the episodes, the students' main activity is to together construct perspectives appropriate for each particular task or prompt: building a wave and then reversing its direction, or explaining how their strategies had worked. The perspectives were constructed collaboratively—by being positioned as a source, each person would suggest a new perspective, and the listeners would respond with suggestions for re-framings or by introducing limitations of conceptions that might constrain their use of the perspective offered. The group's final explanation in Episode 3, that "switching the sign in the equation… to change it," was uttered by Bryan, but was first introduced by F and further motivated by pushes by individual students (particularly E and F) for a mathematical framing; D contributed information about the correct representational form of the equation (and correct placement of the sign); B and E performed the apparent justification for this explanation together by "mapping" equation terms and variables to elements of the simulation. Thus this "final product" should be thought of as knowledge that was jointly produced and justified by the group.

Although the activity ended when they had agreed on this "flipping the sign" explanation, the students did not appear to have either shared or similar understandings of this explanation. Instead, the students maintained distinct, personal perspectives which foregrounded different concepts and representations. Bryan, for example, maintained (or would readily reapply) his "source" perspective to new tasks or explanations. While Bryan thus foregrounded relative oscillator motions in space, C's and E's perspectives foregrounded the unit circle representation—and in particular, the progression of points around the unit circle. Because of this, E and C were ultimately able to interpret reversing the sign in the equation as reversing the direction of this progression.

In addition to asking whether the students understood the knowledge they had co-constructed similarly, we can also ask if students appeared to *learn* the same things. What increase in perspectival skill was demonstrated by the students? The students evidenced an increased attunement to the constraints of concepts (for example, constraints of the concept of "phase" for constructing perspectives to explain wave direction), as well as an increased familiarity with the representations of that concept (graphically, mathematically, or on the unit circle). These aspects of conceptual development were interrelated—it was only after the correct form of the equation was determined that the students dropped the constraint that "phase shift" should be represented as a discrete graphical shift. However, B's increase in skill in constructing perspectives was strongly tied to his repeated application of his "source" schema. E, on the other hand, did not readily apply this schema himself, instead increasing skill in constructing perspectives which foregrounded the unit circle representation.

The students' distinct framings were productive, driving the group to come up with a mathematical framing that would explain wave direction, as well as why B's "source" strategy had worked. It is worth noting that a mathematical explanation was not required or even suggested by the task prompt—it is likely only due to the students' epistemological framings that a mathematical understanding would be preferred. This ultimately led them to attempt to coordinate the wave equation with the phases of individual oscillators along their wave. B's foregrounding of relative motion, and C's foregrounding of the unit circle, coupled with this epistemological framing likely led to C's to attempt in Episode Three to construct a perspective foregrounding the wave equation,

unit circle, and relative oscillator motions all together. While conceptually very difficult, relating and coordinating those various concepts is at the core of a deep understanding of the physics of mechanical waves.

Conclusion and implications

As ours is a design-based research project, we intend for the implications of our analysis to be both theoretical and practical. As the students' differences in perspectives and framings provided opportunities for deep conceptual learning, we consider purposefully supporting *divergent* ways of thinking, and then sense-making across them. This might be accomplished by giving the students slightly different views of their shared wave—making some representations available (or more prominent) to some students, and a separate set to others. In this way, the technology itself may suggest to students which elements and representations might be foregrounded in their perspectives. A diverse set of foregrounded concepts may, as happened in Episode 3, lead the students to work out the relations between and coordinate the relevant concepts and representations. It is possible that in our current design environment the tasks posed to the students—to construct primarily *verbal* explanations—did not sufficiently demand coordination between these different representations of concepts. A task in which students were asked to embody these conceptual understandings in a shared artifact may require more agreement about, in particular, which representations of concepts should be foregrounded in the group perspective.

Our analysis also speaks back to some central theoretical topics of research in collaborative learning. The main theoretical implication of this work is that we need not focus on convergence, sharedness or similarity of individual understandings as an indicator of good collaboration—or even as a desired outcome. Instead, we find that divergent perspectives can maintain tensions that are productive for learning even if they are not ultimately reconciled. Further, we suggest that conceptions of *group learning* need not rely on similarity, overlap or agreement between individual conceptual understandings. Instead, we may take learning, at either level, to be an increase in skill in constructing perspectives. The individuals in a group may develop and apply different perspectives, and may increase skill in doing so in different ways. At the same time, the group *as a whole* also can increase in skill in constructing perspectives, but the process by which it does so is a *social* process involving positioning and constructive listening, which organizes and evolves the group perspective under influence of the distinct individual perspectival understandings and framings. This points to a way of conceptualizing "group understanding" without relying the on the similarity, sharedness, or convergence of individual understandings.

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Acknowledgments

Students Using Graphs to Understand the Process of Cancer Treatment

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Abstract: Scientists rely on graphs to make predictions, interpret data, and articulate arguments about the phenomena they investigate. Yet, students' initial formal experiences with graphs are limited, and often restricted to their mathematics classes. We describe how we integrated graphs into a middle school science inquiry unit on cell biology. We report on findings from a classroom implementation with 30 middle school students. We describe students' learning gains and characterize the kinds of graphs they generate in terms of the graphical and scientific understanding demonstrated. This study contributes an example of how curriculum can be designed to simultaneously support students' science and graph understanding. It also demonstrates how graphs can be used as expressive tools that both limit and enable students' explanations of complex scientific processes.

Keywords: cell biology, middle school, graphs, technology, student learning, design

Introduction

Graphs are crucial tools in science. By visualizing data, graphs highlight patterns and events that are not otherwise apparent (Friel et al. 2001; Wu & Krajcik, 2006). They furthermore afford common inquiry practices, such as exploring and making inferences about interactions and processes within complex systems (Shah & Hoeffner, 2002). Although graphs are inseparable from scientific reasoning and discourse, students' first formal encounters with them tend to be restricted to their mathematics courses, and to be presented within self-contained problems that involve only linear functions (Cobb, 1999; Watson, 2008). It is rare that students are asked to use graphs as tools during extended science inquiry activities. As such, they are unlikely to receive instruction on such graph features as non-integer values, oscillations, and exponential growth; features characteristic of graphs used in science, and so that may support students' understanding of complex science topics. This may be one reason for which many students fail to succeed in science (Gal, 2002; Galesic & Garcia--Retamero, 2013; Gallimore, 1990; Jarman et al., 2012).

We describe the design of a web-based unit that integrates graphing into science inquiry with the goal of enhancing students' reasoning about science through graphs. Through its classroom implementation, we explore the value of the unit at improving both students' graphing skills, and their scientific understanding.

Theoretical background: Comprehending, critiquing, and constructing graphs

Competency in graphing involves the ability to comprehend, critique, and construct graphs. Each of these abilities builds on the other. For example, comprehending graphs requires learners to encode visual features (e.g., identify a line's slope or a grouping of points as meaningful); make conceptual relations (e.g., interpret a line's decreasing slope in a plot of human population vs. time as a decrease in numbers of people); and understand these in the context of the relevant discipline (Shah & Hoeffner, 2002). In critique, students must comprehend and evaluate a graph's effectiveness at conveying an argument. Whereas both graph comprehension and critique involve reacting to given information, graph construction requires that learners move from raw data or abstract function, and work within the formal rules of a representational system to visualize relationships (Barclay, 1985; diSessa, Hammer, Sherin, Kolpakowski, 1991; Latour, 1990; Leinhardt et al., 1990). In spite of the emphasis placed by national standards on improving students' graphing competency, graphs receive little attention in instruction, likely because they receive little attention in standardized assessments (Yeh & McTigue, 2009; Miller & Linn, 2013). Not surprisingly, research finds that students struggle in all areas of graphing, from comprehension to construction (OECD, 2006).

Graphing cell division, cancer, and cancer treatment

Our curriculum design and analyses are guided by the Knowledge Integration perspective (Linn & Eylon, 2011). This constructivist framework suggests that students have many diverse, often conflicting ideas, and that instruction should support them in integrating those ideas. Students can be supported in developing coherent

science understanding when instruction elicits their existing ideas, helps them explore new normative ideas, and supports them in the process of distinguishing, organizing, and reflecting upon those ideas.

The curricular context of this study involves a web-based unit on cancer and cell division, called *What makes a good cancer medicine?: Observing mitosis and cell processes*. Authored in the free, open-source Web-based Inquiry Science Environment (WISE, wise.berkeley.edu), *Mitosis* has for several years, been widely used by teachers around the world. In the unit, students are tasked to recommend which of three different chemicals might make the best cancer medicine (that is, the one that most effectively stops cells from dividing). By observing and comparing animations of the effects of different chemicals on cells, students use their understanding of cell division and cancer to write an evidence-based explanation for their recommendation.

A key idea communicated throughout the unit is that cell division is a continuous process. Although scientists have defined and named discrete phases of cell division (interphase, prophase, metaphase, anaphase, telophase), students are reminded that these are simply names to facilitate discussion. The importance of understanding cell division as a continuous process is highlighted in multiple activities throughout the unit. At one point, for example, students are asked to pinpoint the frame in an animation of cell division at which a particular phase begins, an exercise intended to generate debate, and to help students realize that the boundaries between phases are ill defined and subjective. The notions of process and continuity, and the idea of exponential increase in number, which are each relevant to a description of cell division, can be graphically captured in curves. This graph format contrasts with linear and discrete (i.e., bar graphs) graphs, which instead visualize simple processes, or categorical data, but which are also the kinds of graphs with which students at this level are most familiar from their mathematics classes.

In incorporating graphs into *Mitosis*, we aimed to seamlessly integrate the graphs into the narrative of the unit; and to help students gain, through graphing, greater insight into the underlying science. Graphing activities were integrated at two points. Near the beginning of the unit, students learn that cancerous cells are cells that divide out of control (Figure 1). Given a curve of normal cell increase over time, students are asked to draw a curve that best represents the increase in cancer cell numbers over time (Figure 2). Later in the unit, students document the effects of different medicines on cell division based on their comparative observations of animations. They then select one of six graph options that they believe best represents the effects of a successful medicine, and annotate and explain the graph's meaning (Figure 3).

Figure 1. A screenshot from the *Mitosis* unit.
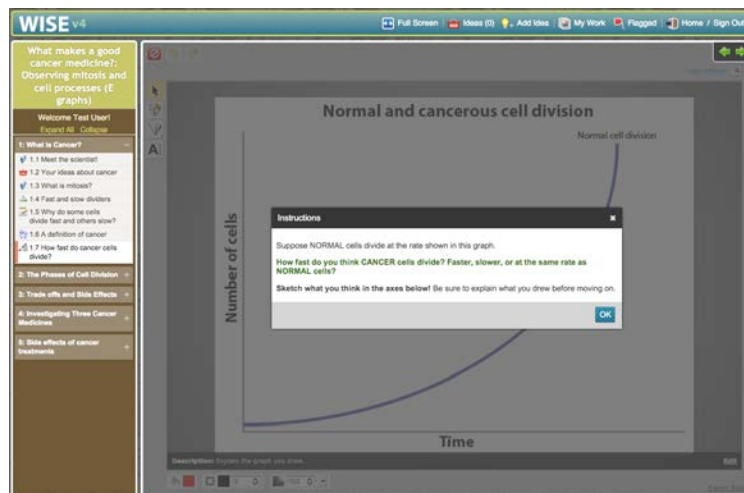
Figure 2. The instructions for the first graphing activity, early in the *Mitosis* unit.
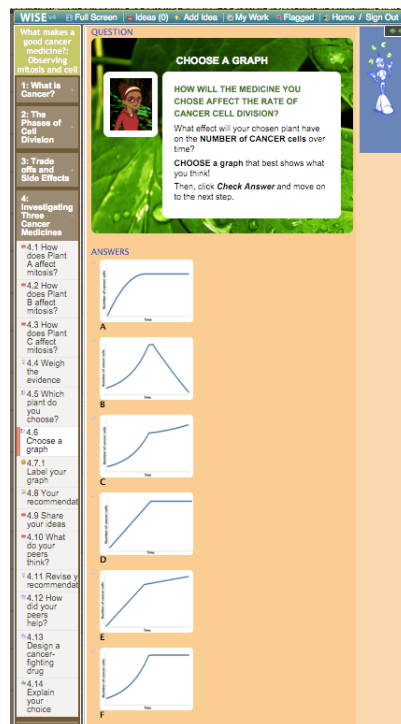
Figure 3. The instructions for the second graphing activity, near the end of the *Mitosis* unit.

Research questions

This research aims to explore the effectiveness of a science inquiry unit that integrates graphs at enhancing both students' science and graph understanding; and to characterize students' changing understanding of the nature of cancer and cancer treatment through the kinds of graphs they generate. Specifically, we ask: (1) Did students' gain in their overall understanding of cell division, cancer, and cancer treatment, by the end of the unit? and (2) What do students' graphs indicate about their changing conceptual understanding of the underlying science?

Methods

We implemented the unit with 30 students taught by one teacher in a diverse middle school in the Western United States. The teacher had more than 6 years of experience teaching with WISE, and had previously taught earlier versions of the *Mitosis* unit, which did not include graphing activities. Although students in this study had studied cell structure earlier in the year, the *Mitosis* unit was their first introduction to mitosis and cell division. It was also their first introduction to nonlinear graphs.

Students worked in partners on the unit for approximately 10 consecutive class periods, during which they also individually completed a pre and posttest. The teacher circulated the classroom and only interjected to offer individual or whole class guidance as required.

The pre and posttest included six questions that targeted students' understanding of the events and the organelles involved in the phases of cell division, and their understanding of how cancer treatment works. The pre and posttest also included a graphing item, on which students were asked to draw a graph to represent the change in numbers of cancer cells before, upon, and after treatment with an effective medicine. We analyzed students' responses to the pre and posttest items, and sought patterns in the kinds of graphs students generated on the graphing item.
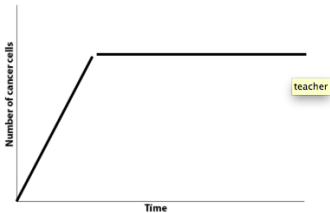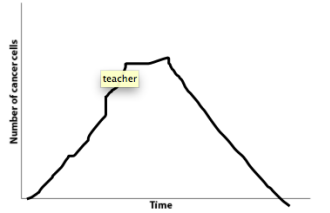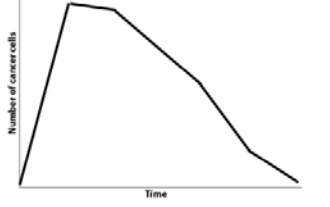
Analysis

We scored the pre and posttest with Knowledge Integration rubrics: 5-point scales that give credit to responses based on the number of links made between normative ideas (Matuk & Linn, 2013). These rubrics were refined by at least two independent coders over multiple classroom implementations, with disputes being resolved through discussion.

The rubric for scoring the graphing item was designed to measure students' ability to graph and explain the effects of cancer medicine on cell division. It involved an holistic analysis of this item's written and graphed components. Scores in this rubric were based on three criteria: (1) the graph and accompanying description cohere, that is, what is described in words is also reflected in the graph, and vice versa; (2) a complete narrative is communicated of the effects of cancer treatment, including a description or representation of before, at the moment of, and after treatment; and (3) the response as a whole demonstrates an understanding that cancer medication decreases the number of dividing cells (Table 1). The highest scoring responses were those that used changes in the graph's shape to support an explanation of the process of cancer treatment.

Table 1. Scoring rubric for the pre and post test graphing item

Score	Description	Example
0	● No response	
1	● Off task	
2	● May address some or all of the following criteria, but none are normative	

3	• At least one of the criteria is met	Description: The beginning of the graph is where cancer starts. Over time the cancer just builds up and up but then when it is treated it turns a sharp right because the cells are being stopped when they try and do mitosis but the cells will still stay alive. enlarge
4	• At least two of the criteria are met	Description: When the number of cells go up, that's when the cell is undergoing mitosis over and over again. When the number of cells has a straight line on top, that's when the medicine is injected. When the number of cells falls, that's when the medicine kicks in and ends the cell cycle. enlarge
5	• All the criteria are met	Description: In the beginning, the number of cancer cells are increasing very rapidly, but when it got to a pretty high point where there were tons of cancer cells, the amount decreases just a little bit for a little amount of time, then after a while the drug starts to work and it starts to kill the cancer cell. As you can tell in the graph the number of cancer cells are obviously decreasing its amount quickly. Then after a long time of the drugs working, there are barely any cancer cells left in the end. Comparing to the beggining, you can really see that the drug worked well. enlarge

Findings

All students showed gains from the pre to the posttest, with overall gains being significant ($t(29)=10.97$, $p<.0001$, $M=1.27$, $SD=0.64$) (Figure 4). This result suggests that the unit was successful at strengthening students' understanding of the science underlying cancer treatment.

Figure 4. Overall average pre and post test scores.

Closer analysis of individual responses suggests interesting patterns in the relation between students' developing graphing skills, and their conceptual understanding of the science context. In particular, we note that many students initially drew upon familiar graphical forms from their mathematics courses. Of the 28 students who completed the pretest, eight generated linear graphs (Figure 3) and four generated discrete graphs (Figures 4 and 5) (most of the other graphs were either blank or un-interpretable). This choice of graphs may reflect how students are transferring their prior understanding of graphs (having previously learned to plot points in a coordinate system, and to have constructed bar graphs) to this new science context. However, while each of these graphs demonstrates an understanding that cancer medication decreases the number of cancerous cells, none demonstrates an understanding of this phenomenon as a continuous process. Rather, these students have graphed discrete states in time, leaving it ambiguous as to whether they have truly grasped the complex nature of the topic.

On the pretest, most students who completed item 1.6 either use discrete representations or strictly linear graphs to express their interpretation of the effect of cancer treatment on the rate of cell division. By the posttest, however, no student generated discrete graphs, and only three generated linear graphs. Thirteen students generated piecewise representations (Figure 5, Figure 6) and 10 students generated curved representations (Figure 7). These findings suggest that overall, students gained a deeper appreciation of the continuous nature of cancerous cell division under treatment.

Our analysis furthermore shows how particular graph forms may both limit and enable students in expressing their understanding. For example, students who initially used linear or discrete graphs typical of their mathematics courses generated incomplete narratives of the process, describing only the decrease in numbers of cells, or else, the states before and after treatment. By their posttests, however, these students no longer use grids, nor even mark numbers on their graphs' axes. Instead of being tied to these formal, schoolish conventions, these students now appear to skillfully use graphs for more abstract expression: to illustrate the complex and continuous process of cancer treatment.
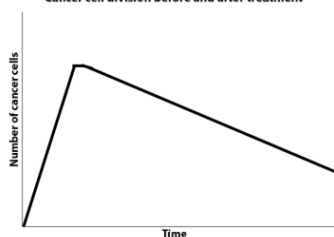
Figure 5. An example of one student's level 2 pre-test response (left), and level 5 posttest response (right), showing how the acquisition of a more complex graphical language was accompanied by a more complete narrative explanation of the process.

Figure 6. An example of one student's level 2 pretest response (left), and level 5 posttest response (right). Initially, this student drew a grid and plotted points at specific coordinates to quantify the decrease in cells. Afterward, this student used several linear functions to build one piecewise function that captures a more complete picture of the process before, during and after treatment is administered.
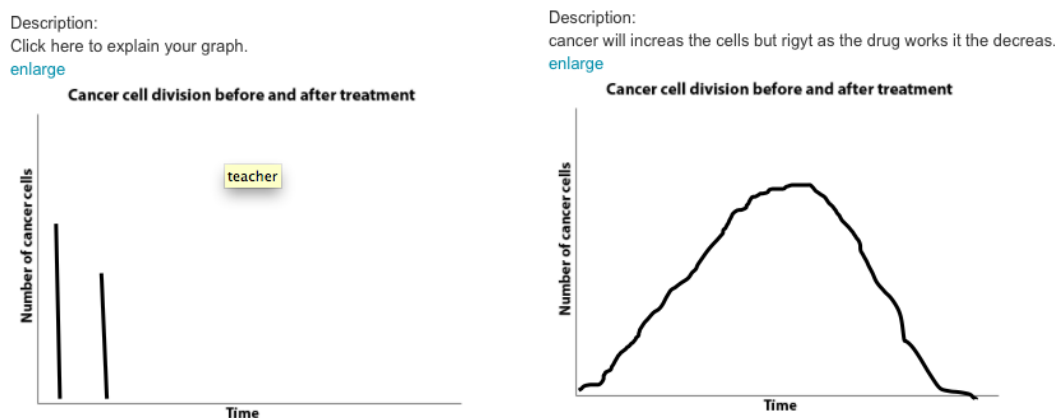
Figure 7. An example of one student's level 2 pre-test response (left), and level 4 posttest response (right). Initially, the student generated two lines, one longer and one shorter, presumably to illustrate a greater number of cells before, and a smaller number of cells after treatment. Afterward, this student uses a curve, demonstrating a more accurate conception of events as being continuous.

Conclusions and implications

This paper described a unit redesigned to integrate graphing to support students' science understanding. Our results suggest that the unit improved students' abilities to explain complex scientific processes in both graphical and written forms.

In particular, students' graphs on the pretest suggested a direct transfer of their graphing knowledge onto the science problem, and not always in a way that was relevant. By the posttest, students' graphs demonstrated a more abstract understanding of cancer as a changing and continuous process. Being exposed to new kinds of graphs through the unit appeared to help students articulate more nuanced understandings of the underlying science. No longer relying on simply linear or discrete representations, students demonstrated an ability to use and even to manipulate graphs to express hypotheses, and to tell stories of a complex process. The fact that even after this brief exposure to continuous graphs, students demonstrate the ability to generate similar graphs, and to explain them within a scientific context, shows promise for the design of inquiry activities that leverage both graphs and science to strengthen students' understanding of both. As we continue to analyze students' embedded responses, as well as the work of students across other class periods and classrooms, we will seek further evidence for what and how students communicate through graphs, and what their graphs may reveal about their science understanding.

In an interview, the teacher in this study commented that compared to her previous enactments of this unit, the addition of the graphing activities appeared to help her students better understand the key idea that cancer medicine should stop cells from dividing. However, another teacher who also used the unit noted that her students struggled to understand the connection between the graphing activity and the underlying science. In our current work, we are thus exploring new curriculum designs that better integrate graphing more seamlessly into this and other science inquiry activities. We are also investigating ways to incorporate graphs into collaborative science inquiry activities (e.g., pooling data and generating collaborative annotations), thereby seeking how to best to leverage social and technological resources of the classroom to support students' science and graph understanding.

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Developing a Geography Game for Singapore Classrooms

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Abstract: This case study presents the design and use of a non-digital geography educational game. The game was co-developed by a researcher and teachers for use in a Singapore public secondary school. Through the game's use, issues of local classroom culture and design arise, including teachers' tendency to define learning in terms of content-based, and the challenges to developing a play-based curriculum. Nevertheless, non-digital educational games provide an old means that may be useful for testing new theories.

Keywords: non-digital games, educational games, learning, design research

Introduction

Though digital games provide a new and exciting avenue for educational reform (Gee, 2004; Mayo, 2009) they continue face barriers to classroom use. Early reports of barriers include technical and logistical overhead for development and support (Van Eck, 2006). More recently, a survey of teachers' perspectives point toward the challenge of finding high quality, affordable games that not only fit into curricula, but that fit into professional practices (Takeuchi & Vaala, 2014). Local cultural views on play and games can add additional barriers, especially in settings where games are not regularly used or are perceived to upset institutional values and norms.

In Singapore, educational game development and research has been strongly supported for the past fifteen years. Despite this support, games are not widely used. The lack of game use has previously been attributed to the way that interest in high stakes standardized testing has posed a strong detriment to their widespread adoption (Chee, Mehrotra, & Ong, 2014). The importance of the standardized tests tends to encourage the use of tools with the best track records, and tends to discourage major shifts in pedagogy or practice. Digital educational game use in Singapore is thus inhibited by local culture, in addition to all of the other challenges games' often face (e.g. logistical overhead, finding relevant games). Educational games - especially when coupled with sociocultural theories of learning – may be challenging to use in Singapore because they do not fit well within a context that is characterized by the pursuit of maximizing standardized test scores (Chee et al., 2014).

This is not to say that games *cannot* be used in Singapore classrooms, but that we presently do not know what sorts of games will work. As has been previously shown, digital games like those played in non-classroom contexts (i.e. daily life, for entertainment) may not be a good fit despite supporting educational development with respect to identity or discourses. The purpose of this investigation was to try another approach, non-digital games, and to investigate and report on the conditions of the school and classroom that support game use and to describe the game's design and development.

A design-based approach was used to coordinate the research and development. Development was characterized by iteration and authentic feedback from students and teachers and was driven by a conjecture that game play can support students' learning, especially in terms of systems thinking (Berland & Duncan, In Press) and discourse (Chee, 2011). Because this research conjecture relies on the reliable production of classroom game play, the first goal of this project was to develop a game that produced the phenomena (game play) and to detail its use in context.

Making the case for non-digital educational games

Non-digital games have a long history of use in formal educational practices (Walford, 1969) and an even longer history of affiliated play-based learning theory (D'Angour, 2013). Recently researchers have begun to apply both cognitive and socially rooted theories of learning to understand non-digital games' educational potential (Laski & Siegler, 2014; Siegler & Ramani, 2009). The variety of approaches that have been previously taken to studying the medium makes a comprehensive review of non-digital game-based learning difficult. Even if the review were to be narrowed to STEM, the scope of non-digital game studies includes chemistry (Allsobrook, Brown, & Glasser, 1973; Eastwood, 2013), physics (Smith, 2003), biology (Franklin, Peat, & Lewis, 2003), math (Jiménez, Arena, & Acholonu, 2011), and software engineering (Taran, 2007), to name a few. Non-digital games are clearly an appealing medium for educators, as evidenced by their widespread use and study. Nevertheless, they lack a coherent through-line of research and development that theorizes their relationship to learning and their use in education settings.

Approaching non-digital games as a medium to be studied is not particularly productive, as the boundaries of the medium are always changing. Instead, play-based learning may be more a useful way to connect

studies across the medium. Literature on play-based learning, so far, has been dominated by two lines of research: 1) children and the developmental role of play (Frost, Wortham, & Reifel, 2008; Vygotsky, 1978) and 2) anthropocentric perspectives of play (Caillois, 2001; Sutton-Smith, 2001), including biological and evolutionary explanations (Pellegrini, Dupuis, & Smith, 2007). Considering the influence that Vygotsky has had on theories of play as well as learning, it is slightly surprising that a coordinated, learning sciences-based approach to play-based learning has not gained more momentum.

What *has* gained momentum is the study of a digital game play, especially from social learning perspectives including discourse and identity (Chee, 2011; DeVane, 2014; Foster, 2008; Gee, 2003). Rather than consider play as a universal human activity, rooted in evolution or biology or development, sociocultural approaches have examined a specific type of play-related activity, contemporary individuals' and communities' use of video games. These studies have identified digital game play practices – cognitive and social – that support, lead to, and at times, are no different from academic instances of learning (Gee, 2003). For example, many, if not all, of the learning principles that Gee (2003) describes as being characteristic of good digital games can also be found in good non-digital games. Though it may be seen as odd, this suggests that digital game based learning research can be a useful model for non-digital game based learning.

In particular, designing, developing, and supporting games' integration into classrooms will require overcoming similar challenges, regardless of whether the games are digital or non-digital. Consider for example the case of *Statecraft X*, a digital (iPhone) civics education game designed and developed for use in a Social Studies curricula for 15-year-old Singaporean students (Chee, Tan, & Liu, 2010). In-game, players acted as governors controlling the growth of a town while competing with their fellow students through multiplayer, online play. Game play involved three phases: 1) understanding the game and basic governance, 2) advanced development, and 3) expanding the player's sphere of influence. Through game play, *Statecraft X* conveyed four key themes considered essential to Singaporean governance: "(1) leadership is key, (2) anticipate change and stay relevant, (3) reward for work, and work for reward, (4) a stake for everyone, and opportunities for all."

The game was not designed to be used alone, but to incorporated into a classroom that used *dialogic pedagogy*. Students were expected to learn to *become* particular game-embedded identities (e.g. a *governor*) through cycles of playing the game, engaging in teacher-facilitated dialog outside of the game and then performing actions associated with the game-embedded identity (e.g. a governor) (Chee, Gwee, & Tan, 2011; Chee & Tan, 2012). In short, students would learn about the values and dispositions of governance by becoming a governor.

Though research on *Statecraft X* showed positive results with small groups of students (Chee et al., 2011) it also raised significant cultural and practice-based that would need to be overcome in order for games to be successfully integrated into Singaporean classrooms. First, they found that the students and teachers were not comfortable with the game-based mode of learning, which different significantly from their typical classroom learning practices. Second, using *Statecraft X* pushed teachers into dilemmas related to maintaining the status quo especially with regards to assessment. Generally, teachers were encouraged to explore innovative methods so long as the new methods were able to meet current assessment demands. In this case, a tension arose because *Statecraft* supported the development of a governance-based identity, and because identity development does not show up well on the sorts of standardized assessments that are used to hold teachers and students accountable.

Statecraft X research underscores two points about educational games research and how non-digital games may be particularly useful. The first is well known. Digital games in classrooms must not only exhibit good game design, but must also overcome logistical and pedagogical challenges. Bringing attention to these challenges is useful for developing ways to address them, including differentiating between the challenges that are characteristic of the digital medium (e.g. technical support) and the challenges that are characteristic of game play more generally (e.g. teacher professional development). Non-digital educational games research, drawing on recent sociocultural approaches to learning, may be a useful, low-cost alternative for addressing these latter challenges.

Second, *Statecraft X* may be an educational game by some definition, but that does not immediately qualify it as a game that can be effectively used in a class. Within the genre of educational games, formats vary widely, from complex simulations designed to teach networking to adult learners (e.g. Cisco's subnet troubleshooting game) to math puzzles for kids (e.g. Dragonbox). *Statecraft* research shows that we need a better understanding of the relationship between games and their context of use, especially when that context is a classroom. Pursuing a line of non-digital games research may be helpful for not only theorizing the role of, but also characterizing the nature of and games that work (and don't) within formal education.

The study presented here involved the development of a non-digital game for classroom use. Following the two points above, this report characterizes the game that was created and conveys how the game was perceived and used by students and teachers. Elsewhere, researchers have begun study digital games from ecological perspectives in order to better understand the relationship between games and their context of use (e.g. Shah &

Foster, 2014). Similarly, this study proposes that non-digital games offer a complimentary route for understanding how game-based play can lead to learning in formal education settings.

Theory

Activity theory is used to organize and present the analysis of game play, and was chosen for its usefulness in differentiating the objectives of different stakeholders (researcher, teacher, and students) across the same mediating artifact (Carvalho et al., 2015; Nardi, 1996). Activity theory, developed from the work of Vygostky (1978), Leont'ev (1978) and more recently, Engestrom (1999) and Nardi (1996) is a framework that helps to bridge human activity and consciousness, especially around games (Nardi, 2010). It has been previously used as an analytic lens to characterize game play within online communities (Ang, Zaphiris, & Wilson, 2010), and within serious games (Carvalho et al., 2015). In this study, the top half of the activity theory triangle is used to coordinate the perspectives and objectives of the researcher, the teacher, and the students with respect to the game, and to present a sense of how the game mediates classroom activity across subjects (Figure 1). This study relies on three sources of data to do so: 1) a design narrative of the game's development from the perspective of the researcher, 2) semi-structured post-class interviews with teachers and 3) a video stimulated recall interview of two pairs of students who were recorded while playing the game in class.
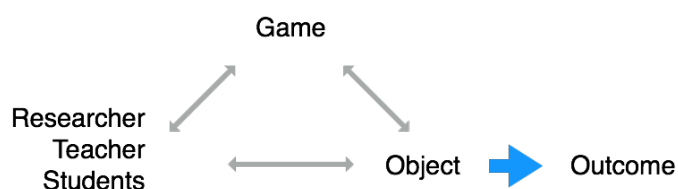
Figure 1. Activity theory was used to organize the data.

The design narrative is a description of the development of the game *Sovereign City*. A design narrative is intended to convey the context of design and in so doing, make explicit some of the implicit knowledge of the designer (Hoadley, 2002). Notes from meetings with teachers, design documents, and prototypes of the game are used as data sources for this narrative. They are combined to tell the story of development from the researcher/designer perspective.

The design narrative is coupled with interviews of two teachers and four students who played *Sovereign City* as a part of their four-week long geography unit. The background of the teachers and their relationship to the project is explained further below. The geography unit that they taught spanned eight classes over four weeks, with classes held twice per week for forty-five minutes per class. The interviews with the teachers were semi-structured, took place two weeks after the end of the unit and included questions about how the teachers thought about the game and its use in class. The interviews were audio recorded, transcribed, and thematically coded.

The interviews with the students were also conducted after their unit finished (two weeks following), and used a video stimulated recall method to prompt discussion. The students were selected for these interviews based on convenience. For each of the two teachers, one class was recorded during game play. The group of four students closest to where the video camera was set up were the students who were video and audio recorded. The two students closest to the camera wore lapel microphones and these were the students who were interviewed. Their interviews were also recorded, transcribed, and thematically coded.

Design narrative: Sovereign City

Sovereign City is an educational card game that's themed around the economics of renewable and non-renewable energy resources. It is based on the deck-building game mechanic found in commercial card games like *Dominion* and *Ascension* with two key differences. First, the basic set of cards it uses is different and simpler than those found in commercial games like *Dominion*. This enables the game to be finished in a shorter amount of time and with less game-savvy audiences. Second, the cards are thematically about energy resources and other topics found within the *Energy Crisis* chapter of the government-approved secondary-2 geography textbook. Otherwise, the primary activity of the game is straightforward and can be roughly summarized: each player takes turns selecting a card to add to his/her deck based on the resources held in that player's hand. As of fall 2015, a version of the game is "done," and a new version is currently being designed for use in Spring 2016.

Before *Sovereign City* development could begin, multiple stakeholders had to be on board and invested in the project's success. The initial teacher-researcher relationship was built by way of a government-sponsored

community-building workshop for game-based learning. Though the teachers who would eventually participate in *Sovereign City's* development did not attend the workshop, another teacher from their school did, and helped set up a meeting. During this meeting, the teachers and researcher discussed project expectations, including timelines, products to be delivered, and research to be conducted. At that point, it was agreed that a game would be developed for the teachers to use in their class, that it would be based on a chapter in their textbook, and that the teachers would have repeated opportunities for feedback regarding the game's design and development. Once the teachers agreed to participate, they then had to seek permission from their administrators, who cleared time within their schedules of work so that they could participate in the weekly design feedback meetings.

The first full prototype of *Sovereign City* was co-developed over five weeks in the summer of 2014. An Agile development approach was adapted and applied, meaning that: 1) A new playable prototype was developed weekly and was used for testing and feedback. 2) Teachers took on the role of customers, providing feedback and design suggestions each week during lunch periods that they donated to the project. The researcher took on the role of developer and Scrum Master, creating the prototypes with the help of an artist. 3) Both the researcher and the teachers had a say in what constituted a "done" product, as determined by the initially agreed upon constraints (Tables 1& 2).

Table 1: Teacher-generated design constraints

Time	The game should be playable within one class period.
Theme	The game should include content provided by the teachers and found within the students' textbook.
Playability	The game should be playable by the target audience (12 -13 year old boys in "normal" and "advanced" classes).
Assessment	The game should, at some point, be able to be assessed using quantitative methods. Ideally, it should be more effective than their typical (lecture-based) approach.
Time	The game should be playable within one class period.

Table 2: Researcher-generated design constraints

Game	The game should tend to induce play.
Materials	The game should be constructed from materials commonly found within a classroom.
Appeal	The game should generally appeal to teachers and students.

Teacher interviews

The semi-structured teacher interviews were conducted approximately two weeks after the unit ended. The two teachers had been teaching for one year and two years prior, and for both, geography was their minor rather than their major subject of expertise. The interviews were focused on questions related to the teachers' views of the game-based learning, and how well or poorly the game that they used fit into their lesson. The teachers' interviews were transcribed, descriptively coded, and organized into themes in order to summarize their views on the lesson and on game-based learning more broadly. The teachers viewed the game largely in terms of its function in achieving the goal of student learning. The teachers used multiple theories to describe how learning occurs in context of using the game, and framed the activity with respect to the importance of conceptual understanding or content.

Games and their functions

For the teachers, using the game in their classrooms disrupted their normal teaching methods. Typically, the teachers explained, they would present the textbook material by way of lecture using slides or videos or assign homework and reading. Playing a game was different for the teachers, as they needed to facilitate the activity and support their students. In order for the game to run smoothly, the teachers had to facilitate students' play, making sure that everyone understood the rules of the game and finished on time, for example. With regards to learning, the teachers saw their role as essential and suggested that their students would not learn much if at all if it were not for the teachers' guidance. Asking questions like, "how" or "why" something happened during game play, the teachers tried to consolidate student thinking and/or get the students to "think deeper" about the material introduced by the game. Additionally, the game provided a context for students to learn how to work with one another and communicate their thinking.

Learning concepts and content

Though the teachers saw the game as useful for their lessons, they differed in their opinions of game-based learning. For one teacher, the students did not learn while playing the game, but learned after game play, when students (with the help of their teacher) connected in-game material to real-world examples or textbook content. If the students were to play the game on their own, the teacher argued, it would simply be "for the sake of playing" and no learning would occur. The second teacher considered that learning occurred while playing, and that the game introduced some of the key concepts from the chapter as evidenced through overheard conversations. For both of the teachers, learning was primarily described in terms of concepts and content, though communication or collaboration was mentioned as an important secondary learning goal.

Video stimulated recall

During the course of the unit, four students were video and audio recorded while they played the game. These four students were selected based on convenience and to minimize disruption. Their seating arranged was determined by the teacher, and so the camera, which was set to the side of the classroom, simply recorded the four students who were sitting nearest. Two students from each group of four were asked to review the recording and to comment on it.

Prior to commenting on the video, the students were shown the first few minutes of the video in order to remind them of the class during which the recording took place. The students were then asked if there was anything in the recording that they thought was interesting, and asked to show researchers where such points of interest were in the video. The students were then asked to comment on segments of interest that had been chosen by the researchers prior to the interview. The selections of video that were chosen by the researcher were any instances of student-student or student-game interaction that were different than quiet turn-taking. For the points of interest (theirs and the researcher's), students were instructed to try to remember and explain what they were thinking and what they were feeling at the time. As is typical in stimulated recall protocol, students were not pressed to respond (i.e. answers of "nothing" were accepted) (Calderhead, 1981). Student interviews were transcribed and descriptively coded. Descriptive codes were organized into themes to summarize students' perspectives on the activity. Three themes emerged from the four students' discussions: rules, time, and personal experiences.

Rules

Student discussions regularly mentioned three topics: explicit rules of the game, fairness/cheating that emerged from breaking or following the rules, and strategies that a player could adopt to win. For both groups of students, the points of game play that interested them were related to rule breaking. For example, the first group of students directed the video to the end of their game. Instead of ending the game, the students chose to continue to play:

> Student 1:   "Like we, we were stunned for a moment when we actually depleted all the, all the sustainable growth cards, and we really didn't know what to do with the, our points, so we just stopped there for a while. Said, continuing playing lah."

Such rule-breaking occurred throughout students' play:

> Student 3:   See I got nothing to do right? So I pick up my cards, then I look, look, look. Then it's like, come, let's make a combo. Then I arrange, arrange, arrange, arrange, see arrange until very nice.

Cheating was a point of contention, and both groups of students policed one another to try to prevent it:

> Student 2:   Yeah, so we were like, I help you shuffle, because we, we, we were like uh, suspecting that he was sort of like peeking at the cards or, something like that.

The students also discussed strategies for winning without cheating, and regularly evaluated their own and other students' choices. For example, they explained that they tried to acquire "better" cards for themselves, and in some instances, tried to undermine other students' play by convincing them to acquire "lousy" cards.

Time

The students were expressly aware of time throughout the game. They watched the clock and discussed whether they would have enough time to finish the game, encouraged one another to hurry up and go faster, and tried to plan their turns while others were playing so that they could complete as many rounds as possible before class ended. At the start of the class while they received instructions from the teacher, and sometimes while they waited to take their turns, students described feeling "sian," a Singaporean word that approximately means ennui, or feeling down as a result of boredom.

Personal experiences

Students also made reference to aspects of their personal lives as they played the game. They made plans for what to do after class, talked about current events, sang songs, and joked with one another. Though these discussions were, for the most part, light hearted and jovial, there was at least one point during game play where interactions were troubling.

As a part of the game, students received cards that represented different countries, including Norway, United States, Singapore, and China. Each country had different abilities related loosely on their current geographic or economic state. For example, the Norway card enabled easier acquisition of hydro-electric energy resources, whereas the Singapore card prevented the acquisition of hydro-electric resources entirely. In the following excerpt, Student 1 had received the China card:

> Student 1: I was being insulted by that person who was sitting beside me. And I still don't like him. He was just… Cause he, he wants to say like, he kind of like want to make fun of the China card then, then say like oh, bad things about it, and like, bad things about me, but then I was like ignore and just continue to play.

As Student 1 later described, his bully regularly tried to make him feel bad for having good (better) grades in Chinese class by insulting him or mocking his accent. Student 1 ignored the comments and explained that he usually tried to avoid being grouped with his bully.

Discussion

The findings from this study are informative for both local development and game-based learning more generally. First, finding that teachers considered game-based learning in terms of content is unsurprising considering prior digital games research in Singapore (Chee et al., 2014) as well studies of its test-oriented culture (Hogan et al., 2013). Assuming that the culture of testing does not change much, designing games for Singapore classrooms therefore means that the games will need to include content found within the government-approved textbooks. Such games may get more traction from teachers if they can provide demonstrable gains in content learning or conceptual understanding. At the same time, the teachers' focus on game-based learning in terms of content may be at odds with contemporary theories of how or why to consider using games for education. Based in situated approaches, many game-based learning arguments have revolved around notions of identity, discourse, and communities. Content learning is not necessarily at odds with such perspectives, but studies and designs of educational games do not typically address cognitive and social approaches simultaneously. If games are to be realistically used in environments that privilege content-based learning that is measurable on standardized tests, then game-based learning studies – even those that take sociocultural perspectives – may also need to show such gains.

Second, observations of student game play suggest that the game's current design does not promote student discussions that the teachers would consider "learning." For the most part, students were strongly oriented toward successfully playing and winning the game (hence, cheating), and socializing with one another. The potential usefulness of the non-digital card game can be seen in the students' motivation to play, and their continued monitoring to keep play going, quickly and fairly. The next design challenge is thus to take students' interest in continuing to play and to leverage it for academic goals, especially considering their attention to the game's rules and strategies for winning.

Finally, in this example, the design and use of a non-digital game in a Singapore classroom recreated many of the learning opportunities as well as the challenges that prior digital games faced. Similar to *Statecraft X*, the card game required structured support in order for it to be effective and it raised issue with as quantifiable and content-based. Though the current classroom culture in Singapore may not be well-suited for the type of learning promoted by *Statecraft* curriculum, non-digital games may be more easily adopted, and may provide a way to enact gradual change.

Conclusion

Designing educational games for classroom use requires principles of good design, including iterative development and testing in authentic settings (Gaydos, In Press; Hoadley, 2002). Non-digital games provide a low-cost way to quickly cycle through this development process, potentially enabling faster identification of the cognitive and social drivers that support effective educational game use. Quickly getting games into the hands of teachers also provides opportunities for authentic feedback regarding how play fits into their pre-existing practices and more generally into their curriculum. Though card and board games may be somewhat disruptive, especially for teachers interested in maximizing test scores, they are sufficient for creating the phenomena of interest, *play*, an essential first step to investigating game-based classroom learning.

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Secondary Teachers' Emergent Understanding of Teaching Science Practices

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Abstract: The Next Generation Science Standards (NGSS) are the latest reform of science education in the United States. The new standards are a radical departure from previous standards in their focus on science practices. Not only have general notions of inquiry been replaced by specific science practices students should learn, but the standards articulate a vision of instruction that places student engagement in science practices as the means though which science concepts should be learned. Teacher educators recognize this shift places profound demands on teachers and teacher learning. We report evidence from the start of an NGSS professional development project on how teachers' understanding of the science practices emerges from their efforts to re-design instruction to align with them. Our analysis suggests teachers' initial understanding is quite far from the vision of NGSS. We characterize this understanding and consider its implications for teacher professional development.

Keywords: teacher learning, science teaching, professional development, NGSS

Introduction

New science education standards being introduced in the United States are recognized as placing substantial, new demands on science teachers (Moon, Michaels, & Reiser, 2012; Pruitt, 2014). The major shift in the new standards is that science concepts are to be learned through engagement in science practices, such that students develop deep understanding of both disciplinary core ideas and the practices themselves. While this sort of integration has been pursued in the science education research community for decades, and in fact underlies the new standards (NRC, 2012), it remains rare in typical U.S. schools. There is a great need, therefore, for professional development (PD) opportunities for working teachers to understand and learn to enact the teaching demanded by the new standards.

Any effort to help teachers learn the new reforms has to start from knowledge of teachers' initial thinking about the NGSS and its implications for their teaching practice. We report here on an attempt to get such knowledge, as part of a professional development project that aims to help a group of secondary science teachers learn to teach to the NGSS. We ask two questions. One, what do teachers see as their goals for their students' learning? That is, what are they trying to accomplish? Answering this question informs how teachers might interpret the NGSS in relation to their own goals for students. The second question is, how do teachers understand the science and engineering practices (SEPs) articulated in the NGSS and how they relate to learning core scientific ideas? We consider teachers' early participation in professional development activities as contexts to elicit their initial thinking about what it means to teach toward the new standards.

Core practices of ambitious teaching

Our perspective on teacher learning, and hence professional development, is derived from the idea that a small set of "core practices" underlie ambitious science teaching (Kloser, 2014; Windschitl, Thompson, Braaten, & Stroupe, 2012). By ambitious, we mean teaching that supports students taking on the intellectual responsibility for their own learning, as articulated in the conceptual framework underlying the NGSS (NRC, 2012). This includes students taking responsibility to engage in meaningful versions of science practices like asking questions, designing and conducting investigations, collecting, analyzing, and interpreting data, making models and arguments from such interpretations, and so on. Our view of such science practices is that they are fundamentally dialogic (Kelly, 2014; Mercer, 2009; Ryu & Sandoval, 2012). From this view, we see two primary demands on teachers' practice to align with NGSS. One is that classroom activity has to be opened up to students' agency and meaningful participation. Students need ongoing and extended opportunities to engage in science practices as the means to make sense of science concepts (Osborne, 2014). The second demand on teaching follows from this opening up of opportunity: teachers must be able to manage productive disciplinary discussion among students, discussion that holds students accountable to each other and to disciplinary standards of knowledge production (Engle & Conant, 2002; Michaels, O'Connor, & Resnick, 2008).

Little is yet known about how best to support teachers learning to teach in ways aligned with NGSS. Specifically, there is scant research on teachers' understanding of the eight core science practices described in

NGSS (NGSS Lead States, 2013). Of these practices, argumentation has received a great deal of attention over the last decade. It is now well established that many teachers have an understanding of scientific argumentation that reveals many of the same limitations as students' arguments, and these limitations negatively affect their efforts to teach the practice (Beyer & Davis, 2008; McNeill & Knght, 2013; Sampson & Blanchard, 2012). It is also very well established that the typical science laboratory experiment is intended to help students verify a concept or principle already taught through other means (NRC, 2005). This suggests that in-service teachers should probably not be expected to have a deep understanding of the core science practices articulated in the new framework, and may not understand how practices are the means through which science knowledge is generated. Professional development efforts very likely need knowledge of teachers' conceptions of the core science practices.

It is by now, however, well established that links between teachers' beliefs and knowledge about science and science teaching and their actual teaching practice are tenuous and hard to trace (Bryan, 2012). Our view is that an important means to get at teachers' understanding of the new science practices is to examine the opportunities they provide to students to engage in them. A more accurate way to put this may be that it is important to document the versions of science practices that teachers promote in their classrooms, and examine the alignment between such versions and the versions idealized in the NGSS. We take this approach here. Moreover, while we acknowledge that what teachers say is important may not be directly reflected in what they do in the classroom, we still think it is necessary to get some idea of the goals teachers have for students. What is it teachers want students to take away from their science classes? Our expectation is that as teachers open up spaces for students' epistemic agency and accountability, they may begin to formulate different goals for science teaching, goals that may be specifically grounded in notions of the value of students being able to engage in particular science practices.

Methods

This study asks two questions. What do teachers express as their goals for teaching science? How do teachers understand the science and engineering practices (SEPs) articulated in the NGSS and how they relate to learning core scientific ideas? In answering these questions we aim to generate insights into how to support teachers in learning to teach to the NGSS. The question of how teachers understand the SEPs and their relation to disciplinary core ideas is an obvious practical issue raised by the new standards, as helping students explicitly relate science practices to the ideas such practices produce is a major goal of this reform. Understanding teachers' goals for science teaching, generally, helps us to relate how those goals may or may not influence teachers' understanding and uptake of the new standards and efforts to implement them.

Study context

This study draws on data collected in the early months of a multi-year professional development project. The overall project aims to help teachers shift their practice toward the kinds of science learning envisioned by NGSS, learning that relies on students' joint construction of scientific knowledge, and of the practices that create such knowledge. Since our view on creating such learning environments sees students' collaborative, accountable talk (Michaels & O'Connor, 2012) as the primary means of learning, our efforts are focused on helping teachers learn to manage such talk. Our approach has two stages. In the first stage, our aim is to help teachers "open up" their instructional activities to give students more agency and responsibility to negotiate and enact practices of experimentation, modeling, data analysis, argument, and so on. Productive disciplinary discourse can only emerge in such contexts, where students legitimately have to grapple with how to engage in the work. The second stage aims to help teachers learn productive talk moves that can help them manage the student discourse arising from these more open opportunities to do science. The data reported here come from the beginning of the first stage of the project.

The professional development work from which data are drawn for this analysis includes a series of sessions totaling nearly 30 contact hours with teachers over the first two and a half months of the 2015-16 school year. Professional development activities are led by dedicated staff experienced in science teacher professional development, in collaboration with research staff on the project. The project started with a 3-day summer institute (18 hours) where teachers were introduced to the NGSS, discussed the foundational assumptions underlying the new standards, and experienced themselves two extended learning experiences intended to engage them in science practices in ways aligned with the new standards. The institute was followed by three more PD sessions totaling 10 hours. Teachers organized themselves into grade level and subject matter teams spanning multiple school sites (e.g., grade 6 life science, high school chemistry), and pursued, with project staff support, a version of lesson study cycles (Fernandez & Chokshi, 2002). During this first stage of the project, lesson study was framed around the choice of one SEP to teach, according to the teachers' developing understanding of the practices in NGSS.

Data for this study are drawn from the initial project summer institute (August 2015) and PD sessions and classroom observations leading up, but prior, to the first set of instructional rounds of lesson study. We treat these initial sessions of PD as contexts in which teachers' emergent understanding of science practices can be observed and documented.

Participants

The teachers involved in the project work in an urban school district in the western United States, serving a population of just over 30,000 students. Ninety-five percent of students identify as Latino, more than two-thirds qualify for free or reduced lunch, and approximately 30% are classified as English learners. All participants (N = 26) teach science at the secondary level, grades 6-12. Twelve (9 women, 3 men) are middle school (grades 6-8) teachers, and 14 (10 women, 4 men) teach high school (grades 9-12). All participating teachers are designated as lead teachers at their schools, with responsibility for helping their colleagues implement NGSS. Most of the high school teachers participating in the project worked with this project's professional development staff during the year prior to the start of this project. Nineteen teachers were present for the initial 3-day summer institute, and the other 7 joined at the first fall PD session.

Data sources and analysis

Our data on teachers' expressed goals come from a brief written reflection activity they were asked to complete at the end of the first day of the summer institute, as well as group oral responses from a discussion of foundational assumptions of NGSS (NRC, 2012, pp. 24-28). Responses were analyzed thematically, by grouping similarly worded responses together and labeling them. These labeled groups were constructed independently by a researcher and then discussed and revised by the research team.

Data on teachers' practices with respect to SEPs and their integration with disciplinary ideas are drawn from artifacts teachers produced during PD sessions, generally working in their lesson study teams; video records and field notes of all PD sessions; written classroom observations of each teacher during the first 6 weeks of the school year, 36 observations in all; and classroom observations (in person and video recorded). Field notes of PD sessions included a chronological account of the PD activities, including detailed transcripts of facilitator questions and teacher responses during whole group discussions. Written classroom observations described the instructional activities, documented teacher-student interaction (e.g., question-response sequences) during the class observed, and specifically tracked teacher talk moves derived from the accountable talk framework (Michaels & O'Connor, 2012)

To explore teachers' ideas about the SEPs, we identified moments in the PD sessions where teachers described student participation in the science and engineering practices (both verbal and written). We focused on trying to understand teachers' ideas about what students would be doing differently with the NGSS. To analyze classroom observation field notes, we identified the specific science and engineering practice that was used during the lesson and described student participation during the class. We focused on understanding students' agency in the science and engineering practice used during the lesson. We determined the degree of student agency by examining students' roles and responsibilities during classroom instruction. For example, in a cookbook, known answer lab, students' roles are largely structured by the teacher where they have little autonomy to decide how to approach and/or solve the scientific problem at hand. While this type of teacher driven instruction was very common in the classrooms we observed, there were a few where students had greater opportunities to share their own ideas and decide on approaches for solving scientific problems. In both cases, our analysis aimed to identify the different purposes or goals that teachers pursued in these classroom activities.

After writing these descriptions, we read through and grouped them based on similarities in teachers' ideas about the science and engineering practices and student participation in these practices. From these groupings, we developed themes to characterize the descriptions in each group. Our themes depict teachers' instructional goals as represented by their ideas about student participation in the science and engineering practices and how they enacted those ideas in classroom instruction. Thematic labels are expressed in terms of the learning goals each grouping appeared to reflect.

Findings

We briefly discuss teachers' statements of their broad goals, or perhaps hopes, for their students. Then we present analyses of baseline observations of teachers' classroom instruction and their talk during PD sessions. We argue that, together, these expressed goals and initial observations depict their emerging understanding of science practices articulated in the NGSS.

Goals for science learning

The 19 teachers attending the summer institute wrote 23 statements of goals for their students' science learning. Note that these statements were rather brief, thus they tell us mostly what teachers consider important for students to get out of science classes in a very broad sense. Perhaps not surprisingly, most teachers focused on various kinds of skills they hoped students would develop from their science classes. Twelve teachers made statements related to students learning skills. Four of these statements were general statements of skills of "critical thinking" or "problem solving strategies." Four others expressed "communication" as a goal, such as "great public speakers" and "good at sharing their thoughts." Only three of skills goals were expressed in terms specific to science; these were "back up claims with evidence," "develop their own experiment," and "problem solving with scientific methods/SEPs."

A second set of goals related to a love of science, a phrase used by four teachers, a fifth teacher wanted students to become interested in science, and a sixth hoped students would develop a "wonder for more." Three statements expressed a hope their students would be ready for future academic work, in science and in general. Two statements referred to personal development (e.g., "being responsible"). Taken as a set, teachers' statements of goals were not only broad, but articulated no specific connection to science as a subject.

We see these sorts of goal statements as articulated at such a high level as to bring no traction to considerations of teaching practice. In one sense, they are unassailable. They are also not functional. We are cautious about reading too much into such statements, given the context in which they were elicited. Nevertheless, we see the generality and vagueness of these statements as at least suggesting the possibility that these teachers had not thought about the value of learning science in specific terms.

Use of science practices

Our interest in how teachers make sense of the SEPs articulated in the NGSS is in relation to their own teaching. One might ask what teachers think modeling or experimentation or argumentation are as practices of science. Here, we are interested in how teachers organize student engagement in SEPs in instruction. The themes we derived to characterize these perceptions are summarized in Table 1, in descending order of their frequency in our sample.

Table 1: Teachers' instructional goals for engaging students in SEPs.

SEP is to…	Student participation is intended to…
Reinforce concepts	Demonstrate understanding of a concept through a structured activity.
Engage with topic	Generate interest or relevance through an introductory activity related to a topic.
Learn method	Develop understanding of the scientific method, unrelated to current curricular topic.
Assess concepts	Demonstrate understanding of a topic at the end of an instructional unit.

Reinforce concepts

The most common idea about the SEPs was that they can be used to reinforce science concepts learned in previous class sessions. For example, teachers may provide some direct instruction prior to students building a model or doing an experiment to reinforce their understanding of the concept. Students' engagement with a practice in this case is similar to the traditional verification lab. The point is not to explore a phenomenon or generate an idea or explanation, but to demonstrate a concept. Such activities mostly focused on the practices of conducting investigations, modeling, or analyzing and interpreting data.

For example, in a grade 8 physical sciences class, students watched and took notes on the teacher's presentation of material on volume. They were then given a set of instructions for observing and measuring the amount of water displaced when a cube was placed into a graduated cylinder. In another class, students participated in a structured discussion with two opportunities to discuss with a partner a question posed by the teacher (e.g., careers and instruments used that require precision and accuracy) and then shared out their common response. Later in the class period, students measured water in a graduated cylinder and took the mass of the water in the cylinder. They used these two measurements to calculate the density of water. Student groups performed the measurements five times and calculated an average across their trials. These group averages were reported, used to calculate a class average, and compare that to the previous class period. The measurement and calculation in the lab were not related, explicitly or implicitly, to the earlier discussion.

Other examples of this purpose were more student-centered. In a high school biology class, students were told to develop an analogy for the cell and its structures. The teacher told students to use their notes from the previous day to help them relate the structures of the cell to structures in their analogy. Students used post-its and poster board to draw and annotate their analogy. They used more post-its to explain why their analogy fit the cell structure it represented. These analogies thus were not a means to develop understanding of cells, but to display that understanding for the teacher.

<u>Engage with topic</u>

A second common way to engage students in versions of science practices was a means to introduce them to a new topic in a way the teacher thought would be more interesting or relevant to students. For example, in a middle school class, students were given a small black box and asked to make observations about the box (e.g., the sound it makes, its weight). Students were then asked to make interpretations from their observations about the contents and then finally make a guess as to what was in the box. They were also asked to draw a "model" of what they thought was inside; of course this model was simply a picture of the possible contents of the box.

Another version of engagement involved investigative contexts teachers thought would be interesting to students. For example, students worked in groups to build a roller coaster from insulator pipe, and measured how far and how fast a marble left the coaster. Students dropped marbles on a long foam track with a loop from different heights and measured the time it took for the marble to roll a meter from the track. Students recorded their observations and completed a lab sheet. The purpose of the lab or its relation to scientific concepts was not articulated.

Teachers thought such experiences created interest that could be linked to science topics. One teacher said during the summer institute, "Sometimes the really deep questions happen after the really simple questions and basic observations, like the sun always comes up and down, but that can lead to questions about astronomy." For teachers, engagement in these sorts of preliminary investigations served to create interest to be exploited in subsequent instruction, but were not framed as a means for learning core concepts in a subject. Whereas this sort of engagement could be used to generate questions that could be answered by science concepts, we did not observe such questioning in these activities.

<u>Learn method</u>

Another way teachers engaged students in science practices was to organize activities where students conducted experiments, or constructed models, in order to learn how to do that practice. Such activities were not related to curricular topics and were explicitly intended to help students learn aspects of scientific practice as general skills. As one teacher put it, "At some point, they need to know what the steps are that they need to take. If they haven't gotten those experiences prior, then I can't expect them to do it right away. If they haven't been trained, then I can't expect them to do this, give them freedom to do these things."

These methods-oriented activities were divorced from the topics students were studying. As an example, in a middle school class students followed a written procedure at the front of the class to make "slime" using glue, borax, and other materials. They had been talking about variables the prior day and were investigating the differences in the qualities of the slime produced using different types of glue. While it is possible students developed some interesting ideas about how glue and borax mix, the experiment itself was not related at all to the topics under study in the class. Rather, students were expected to learn something general about controlling variables from their experience. Such activities are profoundly antithetical to the ideas of the NGSS, which specifically aim to place science practices as the means through which disciplinary core ideas are learned.

<u>Assess concepts</u>

One of the ways in which teachers used models, explanations, and arguments was as a means for students to demonstrate their understanding of a topic or concept. As one teacher put it, such artifacts provided a "representation of their knowledge and understanding." For example, students in a middle school physical science class were asked to work in groups to draw a general diagram of the structure of the atom. They worked in groups and drew on a whiteboard. Students labeled the parts of the atom on their model. The teacher moved throughout the room correcting students' models. After all the models were correct, the teacher asked students to copy the model into their notebook. In relation to the NGSS vision of science practices, this example is striking in several respects. First, students' task was to model "the" atom, as if there is such a thing. Second, the model was framed from the beginning as a representation that was either correct or incorrect. Thus, creating the model was not a task of trying to understand the world, but of trying to display an understanding of some version of the world created by someone else. Finally, no aspect of the task engaged students' consideration of how to decide whether or not

a model was "correct" or not, or even what it might mean to call a model "correct" at all. The teacher simply informed students they were right or wrong.

Looking across the set of purposes to which teachers we observed engaged students in what can most accurately be called practical work is just how far these activities are from the kinds of science practices envisioned in the next generation standards. Few activities we observed engaged students as legitimate agents of knowledge production in the classroom. Instead, student activity was primarily directed at discovering or mastering concepts known to be external to the people in the classroom, definitively correct facts and concepts to be assimilated. When students were granted some agency in the form of modeling or experimenting they might conduct, it was constrained within parameters of justifying some concept already framed as correct or demonstrating how classmates' thinking was incorrect.

Conclusions and implications

Our analysis here shows that these teachers' emergent understanding of the science practices in NGSS is not very well aligned with those standards. It can fairly be said that students in our examples were not engaged in practices at all, but merely classroom activity potentially related to science practice. The NGSS explicitly intend for science instruction to be re-organized so that students learn core concepts *through* their engagement in science practices. During our baseline observations of teachers' instruction, we did not see students have opportunities to meaningfully engage in science practices to learn core ideas. Rather, investigative or modeling activities were used to try to engage students, reinforce a concept taught through lecture or reading, assess students' understanding of a concept, or to try to teach some aspect of science process skill divorced from any meaningful science concept.

These findings are perhaps not surprising. These teachers' practices look like typical science teaching in American schools. We take these findings as clear evidence that the learning challenges working teachers face to learn NGSS-aligned teaching are significant. We spent nearly 30 hours with these teachers over 14 weeks, time that appears sufficient mainly to surface their current practice rather than indicate change. As our work with this group of teachers moves forward we see implications that apply to this and similar work with teachers that aims to promote change in science teaching toward an alignment with the next generation standards.

First, teachers clearly need to develop an understanding of how students' engagement in science practices can directly support learning science concepts. The teachers in this sample were not observed providing such opportunities to their students. Teachers with their own research experience are more likely to provide authentic inquiry opportunities to their students (Windschitl, 2003), and it may be that such experiences are critical to help teachers see how science concepts are tied to science practices. That is, teachers themselves need support to develop a "grasp of practice" (Ford, 2008), both the practice of science and the new practice of teaching science. Providing inquiry experiences to working teachers is quite difficult, particularly during the school year. Thus, developing other ways to support in-service teachers in linking science practices and concepts is needed.

One means of providing support for this kind of in-service teacher learning is to reconsider the idea of "rehearsal" that has been developed in pre-service teacher education (Lampert et al., 2013). Rehearsal is a way for pre-service teachers to get highly scaffolded practice with particular teaching routines. In our own work, we see the need to enable such rehearsals to take place within the structures provided by lesson study. As we move forward, we seek ways to coach teachers through particular teaching routines that can help them to open up opportunities for students to engage meaningfully in science practices. Such teaching routines might include strategies to organize sessions for students to critique each others' work (Ford & Forman, 2006), or ways to structure public evaluation of models (Schwarz et al., 2009). The examples we have of such efforts in science education are understood in terms of particular interventions, and perhaps principles, to support student learning, but these have yet to be analyzed and articulated in terms of teacher learning.

Another conclusion we draw from our findings is that teachers' goals for student learning are expressed at such a general level that it is difficult to relate them to science at all, much less consider how they might help or hinder teachers' interpretations of NGSS. Ghousseini et al. (2015) describe their efforts to link instructional routines to the goals those routines serve, goals that may or may not match teachers' current goals. Variations in teachers' goals for their own teaching probably influence how they take up professional development. This is a factor that ours and others' professional development efforts must address, both in research and in professional development itself. That is, we need to help teachers' articulate their own goals in ways that can be compared to NGSS goals and can help them interpret the new standards.

While the purpose of this analysis has not been to validate our professional development approach, we have generated support for our conjecture that opening up opportunities for students to engage in science practices is antecedent to managing productive disciplinary talk. The conclusion we draw from this analysis is how difficult this first stage of creating such opportunities may be for many teachers. Perhaps as the new standards take hold

new curriculum may appear that structure aspects of these opportunities. Our analysis makes clear, however, that these opportunities depend upon an epistemic framing (cf., Berland & Hammer, 2012) that gives students' epistemic agency. Such a framing, we believe, depends upon teachers' understanding of how scientific knowledge derives from specific scientific practices. Professional development must consequently focus on helping teachers learn how to create appropriate epistemic frames around student activity.

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Acknowledgments

Students' Use of Knowledge Resources in Environmental Interaction on an Outdoor Learning Trail

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Abstract: This study examined how students leveraged different types of knowledge resources on an outdoor learning trail. We positioned the learning trail as an integral part of the curriculum with a pre- and post-trail phase to scaffold and to support students' meaning-making process. The study was conducted with two classes of secondary two students. We coded two groups' discourse to examine the use of knowledge resource types in the meaning-making process in an outdoor learning setting: contextual resource, new conceptual resource, prior knowledge resource, as well as the relationship among these knowledge resource types. Next, we also examined environmental interaction and integration in the students' use of these knowledge resource types. Analysis showed that contextual resources are chiefly instrumental in fostering students' capacity to harness new conceptual resource and to activate prior knowledge resource in interacting with and integrating the outdoor learning environment in the meaning-making process.

Introduction

Rapid technological advances have revolutionized the way people learn, as well as redefined learning spaces to embrace learning beyond the four walls of the classroom. Research studies on outdoor learning and mobile learning (e.g., Kerawalla et al., 2012; Maulucci & Brotman, 2010; Maynards & Waters, 2007; Orion & Hofstein, 1994; Sharples, Taylor & Vavoula, 2007) accentuated some similar theoretical convictions: a) the criticality of understanding learners' interaction with the environment endowed with rich physical affordances; b) learners' interpretation of the physical environment; and c) the integration of outdoor learning with indoor classroom learning in the meaning-making process. Orion et al.'s (1997) study found that *active interaction with the environment* is instrumental in meaning-making on an outdoor field trip. Likewise, Frohberg et al.'s (2009) review of mobile learning accentuates the importance of *physical interaction* with multiple resources available in the environments; giving emphasis to the design of learning activities to empower learners to capitalise on the immediate physical space and the *resources* available to enhance the learning context.

Notwithstanding the multitude of studies on outdoor learning, research remains unclear on the meaning-making process: a) how learners use the different types of knowledge resources, in an outdoor learning setting to co-construct knowledge; b) how learners interact with the outdoor learning environment to enhance and/ or advance the different types of knowledge resource; and c) how learners integrate outdoor and indoor learning experience harnessing these knowledge resource types. Building on our previous research on small group collaborative learning, this study explores the knowledge resource types students use on an inter-disciplinary mobile learning trial. We also investigate students' interaction with and integration of the physical environment, where the outdoor learning trail forms an integral part of the curriculum from pre-to-post learning trail.

Theoretical framework

Outdoor learning as environmental interaction

In outdoor learning, students assume an active role in constructing information from the environment where the "*direct experience with concrete phenomena and materials*" (Orion, 1993, p.325) becomes key in the meaning-making process; a process which Kerawalla (2012) coined it the "sense-making process" in her study on students' interaction with the physical environment. The interaction with the physical environment concretizes the otherwise, inert or abstract concept, knowledge and skills acquired within the confines of the classic classroom. Thus, *environmental interactions* form a significant signpost in an outdoor learning context to help students make sense of the world around them. Here, learners are given the authentic platform to attach values and meaning to the objects and the surrounds. Maynards and Waters's (2007) work on outdoor learning for children also underscores the potential of the outdoor learning environment where it fosters the construction of knowledge on a larger scale: exploring the world at first hand and experiencing natural phenomena. On a similar note, Kerawalla et al.'s (2012) work on *doing geography* showed that students develop and acquire new skills not taught in the traditional classroom setting, but through their *situated interactions* with the environment and *improvisational interpretations* of the environment. These new skills emerged as students responded to the challenges in the data

collection process. Apart from skills, the appropriation of knowledge with the real world environment becomes contextualized and assumes meaning through use.

Environmental interaction essentially draws upon two intricately interwoven elements: *learning* and *context*. Sharples et al. (2005) contend that the essence of mobile learning lies in understanding how people "create impromptu sites of learning" as they cross from one context to another. In a nutshell, the context for learning does not reside in the surrounds, but rather it is the learners who give meaning to the context. Here, *knowing* and *contexts* are mutually constitutive; and *learning* is "(re)conceived as fundamentally constitutive of the contextual particulars in which it is nested" (Barab & Krishner, 2001, p.5). This also mirrors Pachler's (2009) notion of mobile learning where learning is conceived "as semiotic work and meaning making in which users develop, with the aid of devices, new cultural practices with and through which they learn and strengthen their resources for meaning-making whilst interacting with the world ... (p.5)". Learners become active agents in the meaning-making process in an outdoor learning setting where they undertake activities to interact with the environment to concretize or create knowledge which culminates in the development of "new cultural practices", and thereby, strengthen their "resources for meaning-making".

Knowledge resources for environmental interaction

As aforementioned, the interaction with the outdoor learning environment implies that learners are engaged in reinterpreting and re-contextualizing during the meaning-making process: attaching new values and meanings to the environmental features (Pachler, 2009). However, this process is not without its inherent challenges. Kerawalla et al.'s (2012) study on students' sense-making process in a geography field trip found that students had to leverage a range of multimodal resources from gesture to prior classroom learning to support their engagement in the interaction with and interpretation of the learning environment. Here, students learn flexibility in their use of knowledge resource types to respond to varying contextualized situations, as well as construct or create new knowledge. Orion and Hoffstein's (1994) works on field trips surface the concept of *novelty space,* which comprises of three essential pre-field variables, namely, the *cognitive*, the *geographical* and the *psychological* novelty. Cognitive novelty is contingent on the concepts and skills learners would be confronted with during the field trip; geographical novelty is related to learners' familiarity with the location of the field trip; and psychological novelty refers to the psychological readiness and inherently, learners' prior experiences with outdoor learning experiences. They observed that students showed better learning performance on a field trip when this *novelty space* is reduced. In other words, the body of knowledge resources made available and accessible for learners' appropriation of these various knowledge resource types during their interaction with the outdoor environment can significantly reduce all three novelty spaces.

From the perspectives of knowledge resources in collaborative learning settings, it is important to examine how learners leverage different types of knowledge resources available to them for knowledge convergence. The body of knowledge resources could be conceived of as a tool that allows groups to have flexibility and manipulation during the interaction with and interpretation of the environment where knowledge resource types can be restructured and approximated to respond and to react to new situations. Fischer and Mandl (2005) examined how students in different collaboration conditions used a range of knowledge resources for process and outcome convergence. Their study identified three core knowledge resource types in the collaborative meaning-making process to construct knowledge: *contextual resource*, *new conceptual resource* and *prior knowledge resource*. Contextual resource refers to the 'case information in the given case'; new conceptual resource refers to new 'theoretical concepts' that students learn within a theory text and prior knowledge resource means theoretical concepts not taught in a theory text, but likely from students' prior learning experiences. Of equal significance would be two other categories of resource use: the relationship between contextual resource and new conceptual resource, as well as the relationship between contextual resource and prior knowledge resource.

Against this theoretical backdrop on environmental interaction and use of knowledge resource types in outdoor learning, our research questions are:

- RQ 1: What type of knowledge resources do students use in an unstructured activity on an inquiry-based outdoor learning trail?
- RQ 2: What is the relationship between the type of knowledge resources and students' interaction with the environment on an inquiry-based outdoor learning trail?

Research Methodology

Participants and research setting

The research study was implemented with two classes of secondary two students (N=40) at one of the future schools in Singapore; a forerunner in the use of emerging interactive digital media-based tools and mobile technologies for teaching and learning both in-and-out of the classroom learning settings, as well as across all subject areas and levels. The mobile learning trail took place at the Singapore River where students could learn about the history of the Singapore civilization, the importance of the river location and the measurement of water quality and conditions. We chose the Singapore River as an ideal location for interdisciplinary learning as students could explore various topics of inquiry by synthesizing history, geography and science knowledge. The outdoor learning trail was conducted in small groups of four to five members, resulting in eight groups from the two classes.

Design of the outdoor learning trail

We position the outdoor learning trail not as a stand-alone, one-day event, but as an integral part of the formal curriculum with a pre- and post-trail phase. All learning activities were co-designed by the research team and the collaborating teachers. The recce trips of the river trail site formed a very critical phase in our design and development process of the overall trail structure: structured activities and the phasing in of an unstructured activity where students could pursue their own inquiry generated during the pre-trail phase. The recce trips enabled collaborating teachers (also the content experts) from the Geography, History and Biology department, to see how the three subjects could lend content to each other in the design of the trail activities.

Table 1 presents the overview of the learning outcomes and lesson activities for each phase. To facilitate the integration of conceptual understanding of the three different subjects on river, civilization and change, an overarching BIG (Beyond Information Given) question on "why does civilization begin at the mouth of a river?" was put in place. Next, the various activities in the pre-trail, as well as during the trail were designed to scaffold and to support the students' inquiry-based learning process and their responses to this BIG question. First, the pre-trail lesson on famous rivers in the world was a tune-in activity for theoretical understanding about the given BIG question. The tune-in activity also enabled students in small groups to develop own line of inquiries relating to the BIG question that they want to pursue during the unstructured learning activity (see Table 1) at the Singapore River Trail.

Second, the outdoor learning trail includes both structured and unstructured learning activities. Structured learning activities refers to the series of tasks designed a priori by the teachers and researchers whereas unstructured learning activities refers to the inquiry tasks that students want to pursue, which were generated during the pre-trail stage in class. To scaffold students' meaning-making process in the structured learning activities, trail activities were designed with a gradual progression from well-structured task-types (performative, and applicational) to less-structured task-types (knowledge generative and synthesis) at the three learning stations along the river (see Table 1 for a brief overview of the trail and task design). After completing all trail activities, students in a small group of fours or fives were given thirty to forty minutes to pursue their own line of inquiry (generated in the pre-trail phase) during the unstructured activity along the river vicinity.

Third, post-trail activities back in class were a measure for summary of learning, follow-up and debrief, allowing groups to share their findings, and attempt a 'rise-above' phase of the progressive inquiry cycle of knowledge building.

Table 1: Overview of Desired Learning Outcomes & Lesson Design from Pre-to-Post Trail

BIG Question: Why does Civilization begin at the mouth of a river?		
Phase	Desired Learning Outcomes	Lesson Activities
Pre-trail (in class)	Students should be able to: 1. develop group pre-trail inquiry and/ or hypothesis relating to the big question. 2. draw connections to similar inquiries and hypotheses at the class level. 3. provide constructive feedback on inquiries and hypotheses presented by other groups.	1. List three famous rivers in the world, their common features and functionalities. 2. Develop one group pre-trail inquiry/ hypothesis relating to the big Q on river and civilization in the web-based platform.
Trail (Singapore River) (Showing	**Structured Learning Activities in the Learning Trail** 1. transfer skills and concepts acquired in the classroom to the outdoor learning	Performative tasks C1: Measure the river water conditions C2: Determine the location for ideal water conditions

only the learning station Clarke Quay)	environment in the undertaking of performative task types. 2. apply the integrated conceptual understanding of the three different subject areas in the knowledge generative and synthesis task types.	Knowledge generative & synthesis tasks C3: Explain why location has ideal water conditions C4: Discuss the importance of water quality
	Unstructured Learning Activities in the Learning Trail Students pursue their own pre-trail inquiry leveraging on the physical affordances of the technological tools and the learning environment. They are free to move around in the vicinity of the river site	Students in small groups pursue their own line of inquiry in this unstructured learning activity (30 min.), to investigate the pre-trail inquiry (i.e. the research questions they developed) and the hypothesis (each pair in the small group of four to five shares an iPad and data-logger).
Post-trail (in class)	1. Identify new ideas/ concepts developed (during the unstructured learning activity) relating to the big question. 2. Synthesize and evaluate findings (pre-trail inquiry and trail tasks) in response to the big question.	1. Class session where students share their collated findings and new concepts developed in response to the big question. 2. Students attempt a rise above to the big question in the knowledge forum, identify new knowledge and concepts and advance their ideas at the class level.

Technology mediation

As an initial study to investigate students' use of knowledge resource types and environmental interaction, the deployment of mobile technologies is intended to empower students to pursue their own line of inquiries, creating their own content with peers on an outdoor learning trail. Each small groups of four to five, was equipped with two iPads and two data-loggers and probes (to measure the water condition). And to reduce the physical presence of the teacher and frontal loading of information, all trail activities were hosted on the web-based platform (see Figure 1). Students were also able to host all their findings and collated artifacts (pictures, data, etc.) on the web-based platform. The provision of the broadcast alerts and feedback features seek to enable immediacy of teacher facilitation and inter-group communication during the learning trail.

Figure 1. Web-based platform hosting all trail activities and customized Google map of trail site
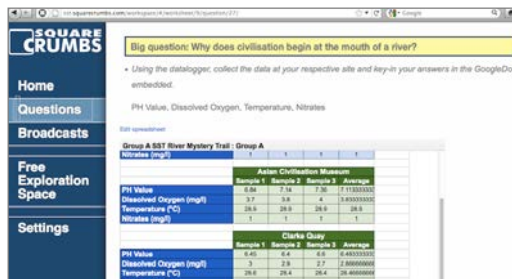
Figure 2. Well-structured task on measuring water conditions at three different sections of the river

Data collection and analytic approach

To examine more closely the use of knowledge resource types and the interaction with the physical environment, we observed two groups of students from each of the two classes. Group A consists of four students and Group B with five students. Group discourse and interaction was video- and audio-recorded and transcribed (appx. 38 pages in total) for analysis. Excluding non-task talk and the sporadic private conversations, we analyzed a total of 113 segments of content- and task-related statements (questions statements inclusive) in the group's discourse. Chi (1997) proposes the use of semantic boundaries to determine the unit of analysis as an idea may require a few sentences to put across. Moreover, similar ideas could be surfaced several times by team members who are more vocal. Hence, each of the 113 segments forms an unit of analysis and may contain one or more than one statements/ question statements depending on the discussion threads, ideas and turn of talks.

In this paper, we focus mainly on how small groups used a range of different knowledge resources types in the unstructured activity, pursuing their inquiries and hypothesis. For discourse analysis, we adapted the coding scheme from Fischer and Mandl's (2005) study where they investigated the knowledge resource types learners

use in the group discourse. Table 2 shows the various categories of knowledge resources defined in this study, considering the outdoor learning context and the curriculum design for our research study. First, we define *Contextual Resources* (CR) as a type of knowledge resource made available at the pre-trail activities, the overarching Big Question, as well as, the trail activities that provide students with the contextual information. Second, *New Conceptual Resources* (NCR) is defined as a type of knowledge resource that integrates the conceptual understanding of the three subjects, Biology, Geography and History and Biology on river, civilization and change, explicitly covered in the textbook. Lastly, *Prior Knowledge Resources* (PKR) refers to a theoretical concept not covered in the textbook. We also examined (a) the relations between contextual resources and new conceptual resources (CR & NCR), and (b) the relations between contextual resources and prior knowledge resources (CR & PKR). The relation between new conceptual resources and prior knowledge resources was not examined, as these two types of resources are mutually exclusive.

Table 2: Coding Categories of Content Dimension (adapted from Fischer & Mandl, 2005)

Categories of Knowledge Resources	Content Dimension
	Descriptor and Sample Statements from Group Discourse
Contextual Resources (CR)	Statement and question statement that explicitly refer to the contextual information related to the pre-trail activities, the BIG Question, as well as the trail activities at the trail site e.g., "...move the port because it was very polluted"
New Conceptual Resources (NCR)	Statement and question statement that refer to the integrated conceptual understanding of the three subjects, arising from interaction with the physical affordances of the trail site. e.g., "...so he (The prime minister) decided to make it into a commercial, residential and entertainment precinct."
Prior Knowledge Resources (PKR)	Statement and question statement that make explicit reference to a theoretical concept, not included in the theory text (also could be activated owing to the interaction with the physical affordances of the trail site) e.g., "Our country saw that trading would not boost the economy".
Relations between Contextual Resources & New Conceptual Resources (CR & NCR)	Statement and question statement that link a theoretical concept within the theory text to the contextual information e.g., "no the trading port wasn't removed. It was replaced, it was replaced to make way for tourist attractions and others."
Relations between Contextual Resources & Prior Knowledge Resources (CR & PKR)	Statement and question statement that link theoretical concepts not in the theory text to the contextual information e.g., "It is because that time when they needed foreign talents..."

Findings

This section addresses the aforementioned research inquiry. We shall begin with RQ1 - presenting the findings of the knowledge resource types both groups used in the unstructured activity on an outdoor learning trail, before proceeding to RQ 2 - discussing the findings on students' interaction with the environment and use of the knowledge resources.

A comparison of the frequency of knowledge resource types used

Figure 3 shows the frequency of the range of knowledge resources for group A and group B. Both groups showed higher use of contextual resources as compared to other knowledge resource types. Another noteworthy finding is that students were able to develop new conceptual resources by harnessing contextual resources. They were also able to draw connections between contextual resources and new conceptual resources in their interaction with the physical environment.

One distinguished difference between both groups lies in both the activation and application of prior knowledge resources. Group B generated higher number of statements (question statements inclusive), showing use of prior conceptual knowledge resource than Group A did (see Figure 3). We also attribute this phenomenon to the nature of pre-trail inquiry generated by each group. Group B's pre-trail inquiry focused on the "*timing of the clean river campaign in the 1980s*" and they hypothesized that some significant events could possibly explain the occurrence of the clean river campaign. Contextual resources drawing on the structured activities were insufficient for their line of inquiry. Likewise, student's capacity to develop and affirm new conceptual resources and/ or see relations between these resource types became unwittingly contained within the availability and accessibility of the resources available at the learning trail. Analysis of the discourse moves in Group B's

discussion and field notes showed them making reference to significant events and developments in Singapore during the researched period. They had to affirm these inferences with authoritative sources on the Internet, before they could eventually construct new meanings and advanced existing prior knowledge. Conversely, Group A's pre-trail inquiry on "what happened to the Singapore River as a trading point, and why it was removed and what is it now?" afforded them greater leverage on contextual resources and the physical affordances of the river site to affirm their new conceptual resources, and to draw valid inferences between contextual and new conceptual resources.
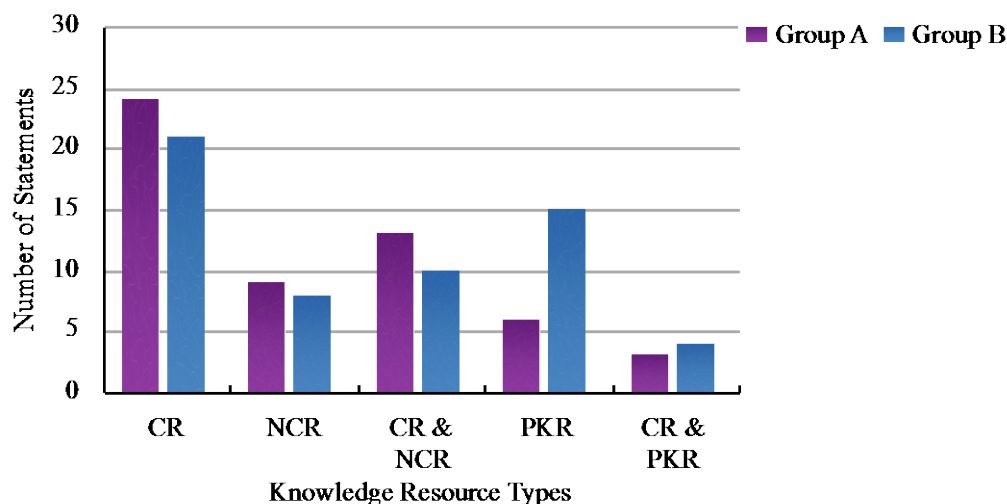
Figure 3. Frequency of Knowledge Resource Types Used in Group Discourse.

Note: CR= Contextual Resources, NCR= New Conceptual Resources, CR & NCR = Relations between Contextual Resources and New Conceptual Resources, PKR = Prior Knowledge Resources, CR & PKR = Relations between Contextual Resources & Prior Knowledge Resources.

Environmental interaction and use of knowledge resources

Relationship between contextual resources and new conceptual resources

By positioning the outdoor learning trail as an integral part of the formal curriculum, the pre-trail activities in the classroom and the structured activities form a significant repository of contextual resources. The provision of pre-trail tune-in activities on famous rivers and the introduction of the BIG question on "Why civilization start at the mouth of a river" are both critical platforms for students to generate their line of inquiry and hypothesis that they intended to pursue during the unstructured learning activity. Albeit that the eight groups from the two classes formulated varied inquiries and hypothesis, yet their intended research inquiries fall within the parameters of the BIG question and the integrated conceptual understanding of the three different subject areas on river, civilization and change. Contextual resources were instrumental for the development of new conceptual resources.

Structured trail activities ranging from well-structured tasks on measuring water conditions to ill-structured tasks on the importance of water quality also form a critical component of the contextual knowledge resources students could use during the unstructured activity where they pursued their own line of inquiry. Figure 3 shows a high usage of contextual resources in contrast to other knowledge resource types. Another reason is the immediacy of contextual resources (trail activities took place prior to the unstructured activity) and the "currentness" of the interaction with the learning environment where learners are empowered to develop new conceptual resources and draw sound relations between contextual resources and their new conceptual understanding (see Excerpt 1).

The structured trail activities significantly reduced the "cognitive novelty" as exemplified in the works of Orion and Hofstein (1994). As evident in Group A's discourse, contextual resources on water quality led to the development of new conceptual resources on sedimentation and pollution. Apart from leveraging contextual resources on water quality, environmental interaction was key to the use of contextual resources and the development of new conceptual resources. Students were able to attach new meanings to the context and construct new knowledge and concepts arising from tourism, boats and pollution. The provision of pre-trail activities and the structured activities in the outdoor learning trail enhances the environmental interaction.

Excerpt 1: Group A's discussion on transforming Singapore River from a trading port to touristic site

Student	Statement	Coding Category
Student C	No, no, the trading port wasn't removed. It was replaced..it was replaced to make way for tourist attractions and others.	CR & NCR
Student G	There's more pollution around the sedimentation...this area because of the...	NCR
Student K	I thought there's more pollution on the other side.	CR & NCR
Student G	There should be more here because there's a lot of ... boats	CR & NCR
Student C	There are more tourists around here, so //the boat has to ferry more.	

Relationship between contextual resources and prior knowledge resources

Students' capacity to draw valid inferences is largely contingent on the environmental interaction to make sense of the contextual resources and prior knowledge resources. Interaction with the physical features of the environment enabled them to activate and concretize prior knowledge during the meaning-making process. This is evident in the discourse (see excerpt 2) between students E and G, as well as students T and E where the group re-contextualised and reinterpreted the surrounds of the Singapore River: they were able to attach new values and meanings to the objects and the features (Pachler, 2009). Next, the activation of prior knowledge resources and the application of contextual resources enabled the students to see the relations between the two types of knowledge resources, as shown in the discourse moves: student E surfaced the vanishing trade of the street hawkers and the plan for more expensive tenants; student Y further advanced this knowledge with his prior knowledge on location, the use of land and the price of land (see excerpt 2).

Excerpt 2: Group B surfacing possible reasons for relocating the port in the clean river campaign

Student	Statement	Coding Category
Student E	Oh because Pasir Panjang had new modern facilities. So they decided to relocate the cargo services.	PKR
Student G	Near my house, near the west.	
Student T	Then what happened to the port here?	PKR
Student E	And also, they renovate the place. So that ... so that there will be a better	
Student T	tenant 'cos it's a very modern thing.	
Student E	Because at that time, there were a lot of street hawkers, so then, they decided to have people who are good at art ... more expensive tenants. So they decided to conserve it and organize the place. Get it?	CR & PKR
Student Y	The basic is that they are trying to raise the price of the land?	CR & PKR

However, the scope and subject matter of the various groups' inquiries do determine to a considerable measure the knowledge resources types they were inclined to use in their group discourse. Group B activated more prior knowledge resources to make valid inferences to their inquiries, as illustrated in Figure 3. Further, in the absence of the physical presence of teachers, Group B made use of the authoritative sources via the Internet to affirm their prior knowledge resources relating to the contextual resources and to draw new inferences. Environmental interaction such as the location mapping and navigational possibilities (e.g., bearings, distance and scale etc.) has given them greater agency to test their hypothesis about the clean river campaign and possible significant events. They were able to locate environmental artifacts as evidences to support their hypotheses and affirm findings.

Discussion and conclusion

This research study reports our initial efforts to explore students' use of different knowledge resources and the relationship of the knowledge resources on an outdoor learning trail. We positioned the outdoor learning trail as part of the formal curriculum (pre-to-post trail) and provided an unstructured activity during outdoor learning trail to investigate students' use of knowledge resources.

Overall findings showed that students leverage heavily on contextual knowledge resources to negotiate meanings, to create new knowledge and affirm findings to their pre-trail inquiries. Also, students were able to develop new conceptual resources and apply prior knowledge resources due to their physical interaction with the trail site. This is evident from a number of their utterances where a particular place(s) and/or significant national event(s) form their frames of reference in making inferences and drawing connections between different resource types. Students were able to concretize knowledge and concepts owing to the immediacy and currentness of

interaction with the rich physical affordances to re-contextualize and to re-interpret contextual and prior knowledge resource.

Our findings carry two important implications on the value of outdoor learning in facilitating the acquisition of knowledge and skills. First, the cognitive, psychological and geographical novelty can be significantly reduced by means of "sufficient" provision of contextual resources. The staging of the learning continuum from pre-to-post trail was a pivotal measure to facilitate the execution of the unstructured learning activity and to provide learners with the contextual knowledge resources. The rich integration of the three subject areas in the design of the trail activities and the framing of the BIG question on civilization and river, serve as crucial cognitive support for the learners. Second, "sufficient" contextual resources are necessary for students to interact with the environment meaningfully to develop new knowledge and concepts.

Although we witnessed some promising results in this initial research study on learners' use of knowledge resources in unstructured learning activities, we acknowledge that there could be limitations such as the integration of other disciplines whose cultural and social practices differ with changing learning contexts. Future research needs to examine how the availability and accessibility of these knowledge resource types works for other disciplines and pedagogical innovations in different learning setting. However, we are persuaded we can equip our students with the necessary knowledge base for harnessing the affordances of outdoor learning.

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Acknowledgement

It Ain't What You Do, It's The Way That You Do It: Investigating the Effect of Students' Active and Constructive Interactions With Fractions Representations

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Abstract: We show that not only the number of fractions representations but also the way how students interact with (multiple) representations is important for their conceptual understanding of fractions. We found that a combination of students' *constructive and active* interaction (e.g., manipulating and constructing representations) with multiple fractions representations as compared to students' *active* interaction (e.g., looking at representations) with multiple representations leads to higher conceptual knowledge measured by students' ability to flexibly represent a fraction. Furthermore, students' representational flexibility was correlated with their general learning performance when students' interacted constructively and actively with representations but not when they interacted only actively with representations. In line with the ICAP-framework we conclude that active interactions trigger more intensively attending processes whereas constructive interactions trigger more intensively creating processes and are thus superior to the first kind of students' cognitive engagement with multiple representations.

Keywords: representational flexibility, fractions, learning with representations, active interaction, constructive interaction

> *'T ain't what you do it's the way that you do it*
> *'T ain't what you do it's the way that you do it*
> *'T ain't what you do it's the way that you do it*
> *That's what gets results*
> *(Melvin "Sy" Oliver and James "Trummy" Young, 1939).*

Introduction

In various mathematical domains representations (such as diagrams) of a concept have, for some time, shown that they are powerful aids to reasoning and problem solving (e.g. Cox, 1997, Larkin & Simon, 1987, Stenning, 2002). More specifically, in the domain of fractions many studies show that learning with *multiple* representations supports students' conceptual knowledge (Charalambous & Pitta-Pantazi, 2007, Lamon, 2012, Liu, Xin & Li, 2011, Rau, Aleven, & Rummel, 2013, Zhang, Clements & Ellerton, 2014). In fact, learning with multiple representations allows students to deal with different interpretations and variations of fractions which in turn supports them to understand the complex nature of fractions learning (Lesh, Post, & Behr, 1987, Silver 1983, Hansen & Mavrikis, 2015). In contrast, an over-reliance on only one representation as for example the area representation might impede students' understanding of improper fractions as the number of partitions cannot be exceeded within this kind of representation (Charalambous, Delaney, Hsu & Mesa, 2010, Smith, 2002).

Nevertheless, research on fraction learning also highlights that simply exposing students to a high number of multiple representations alone is not sufficient as it does not necessarily lead to students' flexible knowledge (e.g., Ainsworth, Bibby, Wood, 1998, Rau, Aleven & Rummel, 2009). In other words, not only the number of fractions representations has an impact but also the *way* how students interact with multiple representation has an impact on their conceptual knowledge. In order to benefit from learning with multiple graphical representations it has been argued that students need to perform cognitive tasks (de Jong et al., 1998) such as making connections between different representations (Ainsworth, 1999, Tabachneck, Leonardo, & Simon, 1994) by identifying differences and commonalities between them. For this, students need to be able to construct and manipulate multiple fractions representations by themselves rather than passively looking at (i.e., being exposed to) multiple representations. Further support for this conclusion comes from the ICAP-framework (Chi, 2009, Chi & Wiley, 2014) that aligns different ways of students' interaction (i.e., interactive > constructive > active > passive activities) to different levels of students' cognitive engagement which in turn have differential effects on students' learning. Through the lens of the ICAP-framework, constructing and manipulating multiple fractions representations display constructive interactions with representations whereas looking at multiple representations

display active interactions. Because constructive interactions trigger creating processes and inference of new knowledge they are more beneficial for learning as compared to active interactions with multiple fractions representation that trigger *only* attending processes.

As in line with Chi's work the higher level of interaction (i.e., constructive) encompasses the lower level of interaction (i.e., active) we hypothesize that students engaging in a combination of constructive and active interactions with multiple representations gain more conceptual knowledge as compared to students engaging only in active interactions with multiple representations in a fractions learning platform. Conceptual knowledge here is defined through one of its core components, that is, a students' ability to flexibly represent (or externalise) a concept of a fraction in many different ways (Deliyianni et al, 2008, Lesh, Post, & Behr, 1987). In addition, we investigate how this specific facet of conceptual knowledge is linked to students' general fractions knowledge as this link might give first hints about students' understanding of different interpretations and variations of fractions.

Method

In order to test our hypothesis, we conducted a quasi-experimental study in England, which was embedded in the larger research project called iTalk2Learn (www.italk2learn.eu). We implemented two experimental conditions with 8-10 year old students from Years 4 and 5. In the first condition students (N =62) were enabled to engage in a combination of students' constructive and active interactions with multiple representations in the learning platform. In the second condition students (N =65) were enabled to engage in only active interactions with multiple representations in (another version of) the learning platform.

Measures

Representational flexibility

In order to measure students' representational flexibility - a core facet of conceptual knowledge - we administered a paper-based pretest and posttest. Both tests required students to write or draw as many ways as they could to show 'one third'. To code the paper-based data as a first step we skimmed through all tests in order to identify which representations students actually generated (see Table 1). Due to the high number of different representations and equivalents of one third, we determined an anchor example for each of the representations and thus ensured correct coding. For each identified representation we coded with 1 point. In cases where students showed more than one example of the same representation (e.g. two circles showing one third or several different symbols showing fractions equivalent to one third) we counted it only once. Across all representations we built a sum score for the pretest and for the posttest.

Table 1. List of students' representations to show one third

• horizontal rectangle (i.e. rectangle split horizontally)	• triangle	• percentage equivalent
• horizontal rectangle equivalent	• irregular shape	• ratio
• vertical rectangle	• 3d figure	• giving 1/3 of a number
• vertical rectangle equivalent	• symbol	• giving an addition
• partitioned rectangle	• equivalent fraction symbol	• giving a subtraction
• square	• comparing one third with another fraction	• explanation or phase
• other rectangle	• number line	• stating one third is dividing by three
• circle	• number line equivalent	• stating/showing one third is one out of three
• partitioned circle	• jug	• showing how one third can be made up to one whole other (e.g. Ferris wheel)
• pizza	• set	
• cake	• equivalent set	
• chocolate bar	• clock/time	
• oval	• decimal equivalent	

Learning performance

As we additionally aimed to investigate the link between students' representational flexibility and their general learning performance we referred to the online pretest and posttest reported in Rummel and colleagues (2016). The online pretest and posttest was concerned with measuring students' procedural and conceptual fraction

knowledge. The test comprised six fractions items including three procedurally-oriented and three conceptually-oriented items. In total students could attain six points as they received one point for each correct answer.
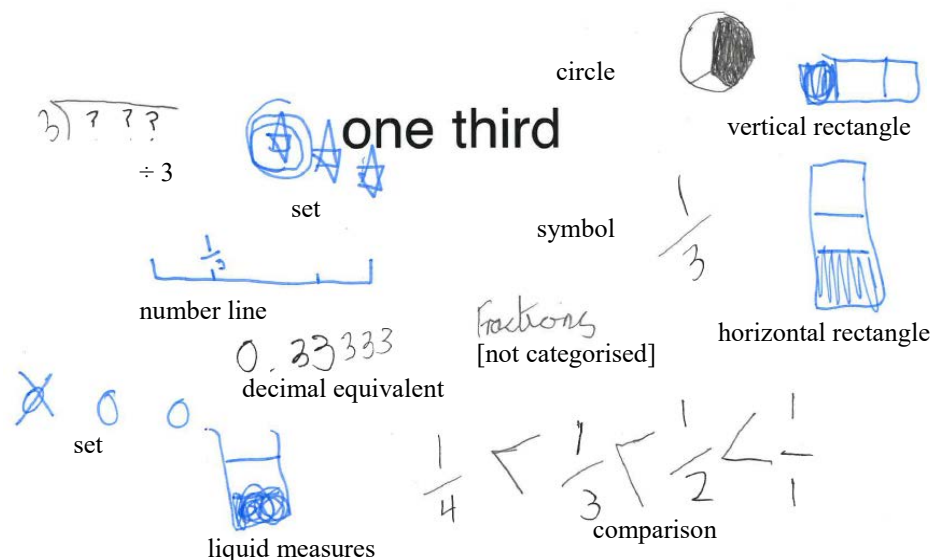
Figure 1. A completed paper-based task to measure students' representational flexibility. Pencil is used pretest and pen is used posttest.

Study procedure

Across both conditions the procedure of the study was the same. In each 90-minute session including breaks involving around 15 students for whom full permissions had been gained. In the first ten minutes, students were introduced to the study and the platform. The students were then asked to spend two minutes completing the paper-based task measuring their representational flexibility about one third, and a further ten minutes filling out the online measures that included students general learning performance (i.e., the procedural and conceptual fraction knowledge questions). In dependence of the conditions, students then had 40 minutes to interact either constructively and actively with multiple representations or to actively interact with multiple representations within (two different versions) of the platform (see section below). After this period students were again provided with the paper-based 'show one third' task measuring their representational flexibility. This time the experimenter asked them to add further representations or to amend the previously designed representations by prompting students to use a pen of another colour. Finally, students had in total 20 minutes time to answer the online measures including the fraction knowledge test (i.e., learning performance).

The learning platform

In line with our two experimental conditions students interacted with different versions of the learning platform. Each version of the platform comprises different kinds of students' learning activities (i.e. exploratory and structured learning activities) that provide two different levels of students' cognitive engagement with multiple representations. In fact, when students engage in the exploratory learning activities they are enabled to *constructively* engage with multiple representations. On the contrary, when students engage in structured learning activities they are enabled to engage *actively* with multiple representations. For condition 1 (see Table 2), the learning platform included a combination of exploratory activities within an exploratory learning environment (Fractions Lab) and structured activities within a structured environment (Maths-Whizz) and thus enabled students to *constructively and actively* interact with multiple representations. To ensure students experienced an appropriate amount of both structured and exploratory learning activities (i.e., constructive and active interaction with representations) the platform essentially switched between both learning environments. Details about the pedagogical rationale regarding how these two environments are combined is explained by Mazziotti and colleagues (2015). For condition 2, the learning platform included structured activities in a structured learning environment (Maths-Whizz) only and thus allowed students to *actively* interact with multiple representations.

Table 2. Outline of the conditions

Condition 1	Condition 2
Exploratory and structured learning activities	Structured learning activities only
Fractions Lab and Maths-Whizz combined	Maths-Whizz only
Constructive and active interaction with multiple representations	Active interaction with multiple representations

Exploratory learning environment: Fractions Lab

Fractions Lab (FL) (fractionslab.lkl.ac.uk) is an exploratory learning environment that was designed and developed as part of the aforementioned iTalk2Learn project. Within the platform it enables students, receiving intelligent feedback, to discover and explore the underlying concepts of fractions by allowing them to constructively create and manipulate fractions representations in the form of sets of objects (small stars, hearts and moons), area (rectangles), number line and liquid measures (a jug) (see Figure 2).
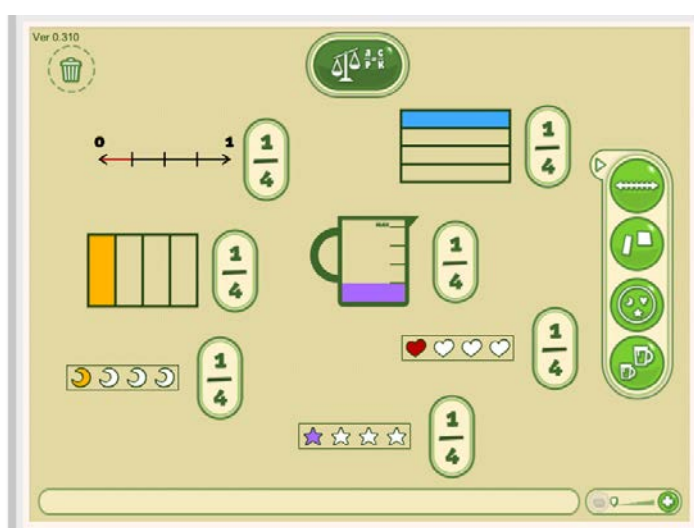
Figure 2. Fractions Lab showing all the representations (number line, horizontal rectangle, vertical rectangle, sets and jug) available to students.

One design feature of Fractions Lab involved the necessity of students to be involved in manipulating the fractions representations and thus to constructively interact with them by completing tasks within the environment. Indeed, students can constructively interact with each of the representations by choosing a representation to use (which is either stipulated within the task or chosen by the student), creating the required fraction(s) and then manipulating the representation(s) by using tools to compare, find equivalents, add or subtract and to partition fractions. For example, by using the partition tool that was designed to encourage understanding of equivalence (Hansen, Mavrikis, Holmes & Geraniou, 2015) students are enabled to constructively think about the relationships within and between equivalent fractions. The constructive use of the partitioning tool is shown in Figure 3.
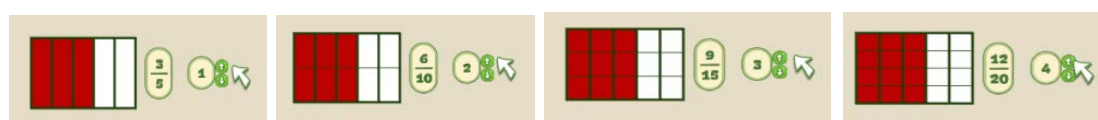
Figure 3. The way how students can interact with representations in condition 1 by using Fractions Lab partition tool. 3/5 in a rectangle, partitioned three times and aligned with the fraction symbol to reflect the new fraction name as the number of partitions changes.

Structured environment: Maths-Whizz

Maths-Whizz is a commercial web-based tutoring system for learning fractions (www.whizz.com) that enables students to actively interact with fractions representations (see Figure 4). Focusing mainly on real-world applications of mathematics, each fractions structured learning activity typically provides a short step-by-step

lesson on how to complete questions and then the student is required to complete further questions independently. Feedback is provided in the form of animations for correct answers and hints for incorrect answers. Because the task context is related to familiar contexts, over 20 representations of fractions are included. For example, it includes sections of a Ferris wheel or chocolate bars (for area representations), ducks swimming on a lake or matches in a box (for sets representations), a train moving along a track or a fairground strength striker game that rings a bell at the top (for number line representations) and comparing liquid or pouring small balls in containers (for liquid measures).
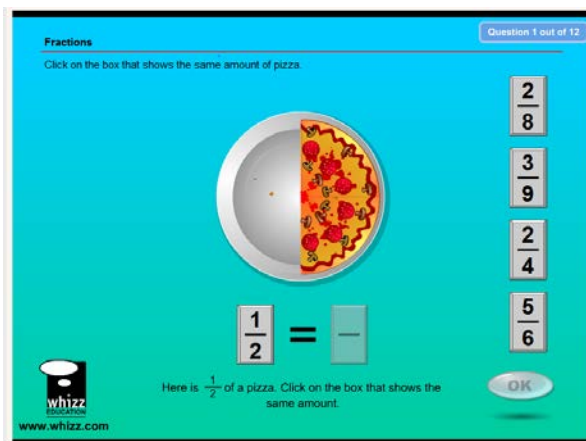
Figure 4. An example of a Maths-Whizz task within the platform. Students are required to select the correct answer from the list on the right after watching an animation of part of the pizza being eaten.

Results

In line with our hypothesis, we first report about the comparisons between students who engaged in both constructive and active interactions (condition 1) and students who only engaged in active interactions (condition 2) with the learning platform. We then outline how students' representational flexibility is linked to students' general learning performance.

Comparing students' representational flexibility

In order to test our hypothesis, we calculated a repeated measures analysis of variance with time of measurement as the within-subjects factor and condition as the between-subjects factor. The repeated measures analysis of variance showed three significant effects (i.e., two main effects and one interaction effect) on the number of representations students used to create one third. First, it showed a significant effect of time of measurement, $F(1, 125) = 250.280, p < .000, \eta_p^2 = .665$: Students in both conditions gained representational flexibility from pretest to posttest. The second significant effect is the effect of the condition $F(1,125) = 5.083, p < .026, \eta_p^2 = .039$. Students who constructively and actively interacted with multiple representations reached a higher number of representations generated in the posttest as compared to students who actively interacted with multiple representations. In line with our hypothesis students from condition 1 did not only reach a higher number of representations in the posttest but as the interaction effect of time of measurement and conditions shows they also gain a higher representational flexibility, $F(1,125) = 10.271, p < .002, \eta_p^2 = .075$. Means and standard deviations of both conditions are illustrated in Table 3.

Table 3. Representational flexibility for showing one third

	Pretest M (SD)	**Posttest** M (SD)	**Flexibility** M (SD)
C1 Constructive and Active Interaction (N=62)	3.16 (1.43)	5.55 (1.83)	2.39 (1.26)
C2 Active Interaction (N=65)	2.91 (1.55)	4.49 (2.21)	1.58 (1.56)

Link between representational flexibility and learning performance

We additionally investigated whether students' ability to flexibly represent a fraction correlates with students' learning performance in dependence of the respective condition. In line with our assumption we found a significant moderate correlation between the number of representations students generated in the posttest and students' general learning performance in condition 1 (r (60)=.436, p=.000). In fact, the more different representations of one third the students created the higher is their learning outcome or vice versa. However, in condition 2 we did not find a significant correlation between the number of representations students generated and their general learning performance (r (60)=.169, p=.196). (Different sample sizes are due to technical issues with some of the online posttests measuring students' learning performance).

Discussion and outlook

It ain't what you do ... The domain of fractions is an essential (Siegler et al., 2012) but highly complex (Charalambous & Pitta-Pantazi, 2007) area of elementary mathematics. Much research has demonstrated that using *multiple* representations enhances students' mathematical knowledge and our results concur, with *all* students increasing the number of representations they generated to demonstrate one third from pretest to posttest. However, when we differentiate between the two experimental conditions our findings also add to the growing body of literature demonstrating that it is not just the *number* of fractions representations matters, but also the *way* in which students interact with multiple representations.

It's the way that you do it ... We were able to confirm our hypothesis that students interacting constructively and actively with multiple representations increases students' representational flexibility. Indeed, students from condition 1 as compared to students from condition 2 generated a higher number of representations in the posttest and also reached a higher gain from pretest to posttest as both effects – effect of condition and interaction effect – were significant. In line with Chi (2009) it appears that the constructive (and active) interaction with multiple representations in condition 1 enhanced students' creating processes such as inferring new knowledge about how to construct a representation which in turn supported students' representational flexibility.

We do not exclude the argument that not only the way students interacted with multiple representations was decisive for their representational flexibility but also the different kinds of learning activities (exploratory learning and structured learning activities) within the different types of learning environments (i.e., FL and Maths-Whizz). In order to be able to conclude more precisely that (only) students' way to interact with representations had an impact on their representational flexibility we propose to use the same learning environment for students' constructive and active interaction with multiple representations (for future research). Nevertheless, by using representational flexibility and not students' general learning performance as (main) dependent measure we specifically pointed students' attention to representations.

The superiority of constructive and active interaction with multiple graphical representations over active interaction is even more relevant when we consider that condition 1 students were exposed to *fewer* representations (and not exactly the same but the same type of representations). It might be that the fewer number of representations allowed condition 1 students to interact more often with the same representations which in turn helped them to become more familiar and more proficient with this lower number of representation over the learning time as compared to condition 2 students interacting with the higher number of representations. Being more proficient with the representations in turn enabled condition 1 students to recall the representations more effectively during the posttest measuring for representational flexibility.

That's what gets results.... We were further able to show a significant correlation between the number of representations students generated in the posttest and students' general learning performance in condition 1: Because condition 1 students were enabled to construct and manipulate multiple fractions representations by themselves rather than passively looking at multiple representations (cf. condition 2) they might have been able to identify commonalities across and differences between different representations (Ainsworth, 1999, Tabachneck, Leonardo, & Simon, 1994) which in turn helped them to extract core components of the representations and the respective interpretation of fractions. Having extracted core components of representations allowed condition 1 students to flexibly apply these components during the general learning performance test. This result once again highlights the importance of interacting constructively with representations, particularly as the correlation between the number of representations students developed in the posttest and the learning performance test was not significant in condition 2.

In order to further unpack students' interaction with multiple representations we plan to conduct an in-depth analysis of our log data and aim to address a series of follow-up questions: With how many different representations did students actually interact with during the learning time in condition 1 and 2? Did students generate the representations they have experienced during the learning time or did they generate completely different representations? Did students tend to engage more intensively in developing equivalent fractions of one

third or did they generate more representations of one third? How was the quality of the representations generated prior to learning with as compared to the quality of representations generated after learning with the platform?

As Suthers (2001) outlines how the choice of a representation can influence an individual's conception (of a problem or task), we further aim to investigate whether students from condition 1 have had a preferred representation when they engaged in an exploratory learning activity. And finally, did the preference depend on students' prior knowledge?

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Acknowledgments

What Happens to the Innovation When Project Funding Ends? Learning Architecture Matters!

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Abstract: The fragility and (un)sustainability of pedagogical innovations is a major theme in the education literature. This study was guided by the theoretical framework that sustainable change requires sustained and aligned learning at multiple levels of the education system, and that greater scale in the innovation affords peer learning at multiple levels. It investigates the sustainability of three e-learning pilot projects in Hong Kong by studying the changes, if any, in (1) the e-learning pedagogical practices (the innovation) that was developed, and (2) the "architecture for learning" that was put into place at multiple levels in order to steer and implement the project, within the first school year after the formal 3-year funding ended. The findings indicate that the nature of the innovation as envisioned and the architecture for learning that was put into place in each project were critical in determining the subsequent sustainability of the projects.

Keywords: architecture for learning, sustainability, learning innovation, multilevel alignment, self-organized learning

Introduction

Since the end of the last millennium, many countries have launched masterplans/strategies for ICT in education as an integral part of aligning the school curriculum with the demands on education for the 21st century (e.g. Denmark 1997; Singapore 1997, 2008; Hong Kong 2004, 2007; Finland 2000; Korea 2000; US Department of Education 2010). To realize the "transformative" potential of ICT to support learning requires the redesigning of teaching and learning activities, which implies a change in the educational markets being served because of the new goals and processes targeted (Oblinger & Hawkins, 2006). On the other hand, computers in schools were found to be "oversold and underused" (Cuban, 2001), and that even when they are used, they have no significant impact on learning outcomes. Collins and Halverson (2009) conclude from their examinations of the apparent lack of impact of ICT use on publicly funded schooling is the intrinsically conservative culture of schools.

This lack of change is exemplified in SITES 2006, a study conducted in 22 educational systems around the world (Law, Pelgrum, & Plomp 2008). While there was a marked increase in reported ICT use in Hong Kong schools SITES 2006 (data collection during 2005/2006) compared to the SITES M1 survey of schools in 1998 (Pelgrum & Anderson, 1999), it was also found that ICT use made little impact on the predominantly traditional ways of teaching in schools. The PISA 2009 results on digital reading (OECD 2011) show that of the 19 countries participating in the study, the Hong Kong results were an exception in performing significantly lower in digital reading than in print. Further, in comparing the digital reading scores between students who used a computer at school and those who did not, Hong Kong's results showed no statistical difference while the mean results of the 15 participating OECD countries were significantly higher for the former. The ICILS 2013 results showed Hong Kong students to have the lowest computer and information literacy mean score among all participating economically developed education systems (Law, Yuen and Lee, 2015a). These findings indicate that pedagogical integration of ICT in Hong Kong schools has not achieved the targeted transformative goals.

Hong Kong launched its first ICT in Education Strategy in 1998. In-depth case studies conducted in 1999 and 2002 on how schools and teachers in Hong Kong have constructed their ICT-using pedagogical practices (Law et al., 2000; Kozma, 2003; Law, Yuen and Fox, 2011) show that even at this early stage, there were some very innovative pedagogical practices involving deep changes in the roles of the teachers and students. Why is that these innovative characteristics are still not commonplace in Hong Kong more than one and a half decades on? This result is not surprising if one look at the literature on school change and innovation, which highlights that sustainability and scalability of educational innovations are the most challenging (e.g. Kozma, 2003; Looi and Teh, 2015). One common starting point of innovations is an externally funded project supported by a government incentive or a design-based research program. The sustainability of these innovations when the fundings end is one major challenge to the impact of these projects. This study is designed as an in-depth investigation of what actually took place in some schools involved in a three-year, government funded e-learning pilot project after the funding period ended to gain further insight into the problem.

Scalability of pedagogical innovations

The biggest challenge to educational reforms or innovations is not to get them initiated or for these efforts to achieve targeted, observable success, but for them to be sustained and scaled. For more than a decade, education researchers have pointed to the complex nature of educational change and sought insight from ecological studies (Hargreaves, 2003; Davis, 2008; Davis and Sumara, 2008). Most of these studies use ecosystems as a metaphor for understanding the multilevel interdependencies inherent in educational change, drawing analogy from change in diverse domains such as climate change and stock markets to illustrate the strong similarity across different forms of complex phenomena: change is non-linear, dynamic and involve nested hierarchies of self-similar structures. Likewise, classrooms are nested within schools, which are in turn nested within districts, provinces, and larger systems. There is complexity at each level and the timescales for change are possibility different at different levels. Complex systems are characterized by the presence of many different feedback loops and interactions such that there is no simple causal relationship. Diffusion models of change (e.g., Rogers 2010) implicitly assume the scaling up of innovations as replication or spreading of successful change. Such relatively linear models are inadequate for explaining or guiding the scaling up of innovations that require the creative input of so called "adopters".

Based on a complex system model of educational change, Coburn (2003) argues that scale does not refer simply to numbers, and put forward a four-dimensional model of scalability (depth, sustainability, spread and shift) that is underpinned by the perspective that the nature of what is being numerically scaled matters, and that the nature of the innovation inevitably change during the process of scaling. Clarke and Dede's (2009) extension of this model to include a fifth dimension, evolution, further highlighted the dynamic nature of innovations during the process of scaling.

Innovations imply changing practices, which require negotiation of meaning among those involved or affected by the change, through interactions in designed and lived organizations (Wenger, 1998). In an implementation study of a new mathematics curriculum in two urban school districts, Stein and Coburn (2008) found that the district designed structure and the nature of cross-community interactions play a very important role in mediating the teachers' opportunities to learn through negotiation of meaning and practice related decisions. Where organizational structures and mechanisms were made available for teachers to make sense of and to *align with* the reform goals (referred to as architectures for learning), much greater ownership and curriculum reform success were observed.

Case studies of ICT-enabled pedagogical innovations grounded on dynamic, complex system models of change found that an important condition for scalability is the presence of supportive *architectures for learning* (i.e., structure and mechanism for communication, collaboration and mutual influence) (Law, Yuen and Fox 2011; Penuel et al., 2011; Law, Kampylis and Punie 2013). In fact, "structures of participation" that facilitate interactions and learning around an innovation need not be specifically designed for the innovation. Pre-existing communities of practice and a culture of open exploration and collaboration could serve as very effective formal and informal architectures for learning. Finnish innovation cases were found to have much higher sustainability than the Hong Kong cases collected in the SITES M2 study because teachers in the Finnish cases were highly connected through joint-school online collaboration platforms and organizational mechanisms for online and face-to-face meetings (Law, Kankanranta and Chow, 2005).

Multilevel, multi-scale framework for analyzing architecture for learning

Pedagogical practices in classrooms are nested within multiple levels of the education system and the wider societal milieu, and scalability issues exist at each of these levels. The European Commission funded meta-study of seven ICT-enabled learning innovations (Kampylis, Law and Punie, 2013) shows that scale matters for scalability. Law, Yuen and Lee (2015b) argue that just as in biological ecosystems where the size of the habitat is one important determinant of the carrying capacity of the habitat for a specific species (and hence its chance of survival), the scale of a pedagogical innovation matters for its sustainability. The construction of highways often pose threats to the sustainability of the existing ecology as the carrying capacity of the resulting isolated spaces become much lower. One way to reduce the environmental impacts brought about by the construction of highways is to construct underpasses that allow animals to circulate across these separate spaces. These underpasses provide the architecture to reconnect these isolated spaces to re-constitute a much bigger carrying capacity. Similarly, for architectures for learning to sustain pedagogical innovations, the architecture has to scaffold interactions and participation not only across levels, but also across units at the same level to achieve some form of scale at each level. They further put forward a multilevel, multi-scale framework for analyzing the architecture for learning in technology-enhanced learning innovations:

1. Aligned learning needs to take place at multiple levels of the educational ecosystem in order that changes can gain depth, spread, sustain, shift in change ownership and evolve.

2. Just as peer-learning is found to be effective for supporting student learning and teacher professional development, learning of school leaders, administrators and policy-makers can be fostered through connected peer-learning within each of these levels within the educational ecosystem.

3. There are four important elements in the architecture for innovation-focused learning: organizational structures that directs and guide interactions; mechanisms for sharing, interactions and decision-making; artifacts that serve as reifications of outcomes of interactions to propagate decisions and advances in understanding; and technology infrastructure that support communications, interactions and knowledge management of individuals and communities.

4. Innovations that have better developed architectures that connect learning across levels and across units would be more scalable in all five dimensions of scalability.

In this study, we adopt this multilevel, multi-scale model for the architecture of learning in the design of our study to investigate whether the sustainability and scalability of the e-learning innovations after the end of the project funding can be predicted and/or explained by the architecture of learning in these schools established in connection with the pilot project.

Research context and method

In 2011, the Education Bureau (EDB) in Hong Kong launched a three-year e-learning Pilot Scheme (the Scheme) in order to develop, try out and evaluate when and how e-Learning works best to bring about effective interactive learning, self-directed learning, catering for learner diversity in different curriculum and school contexts in Hong Kong (EDB, 2011). Altogether 21 pilot projects (61 schools in total) were funded; 9 were individual school projects and 12 joint-school projects. The pilot schools had full autonomy to determine the project foci, organization and implementation strategies, and great diversities were observed across the projects.

Two of the authors participated in a longitudinal evaluation of the e-learning pilot scheme (2011-14, referred to here as Years 1-3). The present paper is part of a follow-up study (2014-16, referred to as Years 4-5) to investigate what happens to the projects in the selected pilot schools after the end of the funding period, as well as whether and how the architecture for learning in these pilot schools changed. In this paper, we report on our findings in three of the pilot schools in the scheme. In order to take the effect of scale into account, the three schools were all selected from joint-school pilot projects. In the context of the application and administration of the e-learning pilot scheme, the EDB required all joint-school projects to identify a lead school that would take key responsibility for the coordination, financial management and reporting of the project. Hence, the lead schools are the de facto drivers of the projects during Years 1-3. All of the three selected schools reported in this paper were the lead schools in their respective projects, which were all considered to have been satisfactorily completed. Table 1 summarizes some basic information about these three schools and the e-learning pilot projects that they led. The research team interviewed the principal, the project core team members and teachers participating in the e-learning pilot at the beginning and at the end of each school year during Years 1 to 5. We also arrange for classroom observation of one e-learning lesson through discussion and negotiation with the project team and the participating schoolteachers, to gain a better understanding of the nature of the innovation developed. In the next sections, we will first report on the observed development of each of the three projects during the pilot period, and whether these were sustained or scaled. We will then describe in detail the architecture for learning in each of these three schools at the project network and at the school levels during year 3 (at the end of the funding period, the architecture for learning should be more mature compared to the earlier years if there had been changes) and year 4, based on detailed analysis of the interview transcripts.

Table 1: Information about the three selected schools and their e-learning pilot projects

School	No. of schools in project network	Education levels (yr 3)	Innovation focus for project	School subjects	Sustainability (innovation)	Sustainability (network)
A	6	P1-P3	Tablets & e-resources	Chinese, Math	✓ ↑	✗
B	5	S1-S2	e-writing platform	English, Chinese	✗	✗
C	10	KS1-KS3	Online platform (TPD)	Chinese & PSHE	✓ ↑	✓ ↑

Sustainability of the three case study schools one year on

The focus of School A's pedagogical innovation as indicated on the project proposal was to foster students' self-directed learning ability and to cater for learner diversity through designing and developing e-learning tools on tablets for the Chinese language curriculum in Primary grades 1 to 3. This pilot project involved six schools. In Year 4, School A continued its practice of using tablets to deliver Chinese language learning activities for students using the online learning platform developed. In fact, the school scaled the Chinese language e-learning activities

to grade 4, and further developed the self-directed learning functionalities of the e-learning platform using the remaining funds from the Project. As the principal mentioned, the goal was to implement e-learning in all school subjects using the online platform for students in all grade levels in the school. At the project level, however, sustainability of the innovation could not be observed in the other five partner schools. Each of the other schools had its own e-learning plan and the network no longer existed.

The pilot project led by School B focused on developing an online writing platform to raise students' interest on writing and to improve their writing skill. A major deliverable from the project was the e-writing platform that provides several supportive tools such as a mind-map to help students organize their ideas, and interaction support functions for sharing and peer assessment. It was expected that with the tools in place, students would be able to practice their writing by themselves and with peers. The project team's focus over the three pilot years was to work with the software company contracted to develop and refine the e-writing platform to ensure that the software was user-friendly and motivating to the students. The e-writing platform was used in the formal school curriculum in Years 1 to 3 in School B. In Year 4, it was only used as one of the supplementary activities for a small group of high achieving students selected to take extra enrichment tutorial classes after school. The project coordinating teacher indicated that other teachers did not really understand what is process writing and found the workload of using the e-writing platform as too heavy..

The pilot project that School C led was very different from the other two in nature. Its focus was to develop an online platform for sharing and collaboration among 10 SEN schools (i.e. schools catering for students with different special educational needs, including various forms of physical and intellectual disability). These 10 schools had in fact formed a network since 2006, which they themselves referred to as the SAME Network. This network was established at a time when the Hong Kong Government changed the secondary school structure from seven years to six and launched a new school curriculum in conjunction with that change. The leaders in these ten schools were of a view that the SEN students should follow the same curriculum, but care has to be taken to adapt and customize the learning activities and resources according to the special needs of each child. Hence they all share the same curriculum ideal: Universal Designs for Learning (UDL), which they believe can benefit teaching and learning in mainstream schools as well. This network of 10 schools had collaborated together in a joint university-school partnership project to implement the concept of UDL in implementing the mainstream curriculum for their SEN students. During this earlier project, the principal in School C realized that technology had great potentials to support the achievement of this goal. In the e-learning pilot project, the focus was to develop an online support platform for teachers on which they could share and discuss adaptations to the curriculum guides to the different key learning areas, specification of attainment levels that can reflect the learning progress and development of SEN students, schemes of work to implement specific areas of the school curriculum. They named this teacher collaboration platform SELTAS (SAME Enhanced Learning, Teaching and Assessment System). Teachers can freely access the system to import their lesson planning data, create resources or download resources relevant to their lessons.

During Year 4, the activities on SELTAS increased, and the network extended their sharing of resources and discussions to cover more year levels, and more teachers participated. According to the project coordinator in School C, they were working on plans to extend SELTAS to include interface adaptations for mobile devices, and to possibly support student learning directly on the platform rather than just serving as a repository for students' learning resources. The project coordinator in School C also mentioned that mobile learning would allow teachers to collect more process data of student learning, which is beneficial to formative evaluation for students. Extending the functionality of SELTAS to include assessment support is one the main visions of School C in setting up the e-learning pilot project.

What and how did School A learn?

The principal of School A, who initiated this pilot project, had a very clear vision for what he wanted to achieve. For him, the core focus was to change teachers' pedagogical practice through using ICT rather than on getting the funds for improving the school's ICT infrastructure (though this was included in the project funding). With his previous experience as an IT teacher to promote e-learning in his previous school, he realized that building a learning culture through encouraging teachers to explore new ideas and to collaborate in experimenting with new classroom practices is key to success in any pedagogical innovation. He organized a core project team for implementing the pilot project, comprising the IT team leader and several Chinese language teachers whom the principal considered to be proactive and willing to try new things. The IT team leader also served as the project coordinator to assist the principal in the project implementation.

The school core team meetings were to plan the curriculum implementation and related changes at the school level to accommodate the change (e.g. timetable, technical support, etc.), as well as the necessary liaison with the publisher responsible for developing the e-learning platform. The main interaction mechanism to support

the pilot scheme implementation at the classroom level was the regular "teacher training meetings" (or TTMs), which involved the school core team and all Chinese language teachers involved in the implementation. The school principal in conjunction with the core team developed a format for the TTMs: Demonstration-Discussion-Collaboration-Observation-Reflection. To begin with, the project coordinator would *demonstrate* to teachers how the tablet might be used in the teaching of a specific topic. This would be followed by co-planning meetings to *discuss* the pedagogical possibilities and issues in such uses in the classroom. After the meeting, teachers would *collaborate* in preparing the e-learning lesson that they were to teach. The principal and core team would conduct regular lesson *observations* and give feedback to the teachers. *Reflection* meetings involving the whole implementation team would also be organized after class.

At the project level, the principals from the six schools would gather regularly to discuss and resolve issues arising from the innovation. The project coordinators also formed an informal communication network to discuss, share and support each other. More importantly, the six school heads made a mutual commitment to each other when they submitted the pilot proposal that there will be monthly "open classroom" observation and debriefing meetings. The participants from each school must include the principal (or the deputy), the project coordinator and at least one subject teacher, and preferably also the teacher in charge of curriculum development in the school. In addition, there will be at least one representative from the textbook publisher in charge of the e-learning platform and resources development. These open classroom meetings would start with the teacher conducting the lesson distributing the lesson plan to all participant observers before the lesson started. Immediately after the lesson observation, there would be a debriefing session during which every observer must provide some feedback. The discussions generally revolve around students' engagement and their learning, the design of learning activities, the role of the e-learning activity and whether that was really beneficial, the design of the software and its compatibility with the subject matter and pedagogical intention, as well as what school supports would be needed to implement this e-learning lesson on a regular basis. The six schools would rotate in hosting these monthly open classroom meetings. These monthly joint-school meetings became a major mechanism for multilevel, cross-school, collaborative learning.

Participating teachers in School A reported significant improvements in their pedagogy and skills through the meetings and peer observations. Examples they gave included: the ability to stimulate and enhance student-student interactions through online collaborative writing and peer feedback rather than just simply using ICT for drill and practice, understanding the benefits of collaborative learning and how to implement it using tablets. They appreciated greatly the feedback received from the principal and the project coordinator, which helped them learn how to evaluate an e-learning lesson and the key aspects to focus on during observations.

In Year 4, the learning architecture for e-learning development within School A remained, with some changes to its organizational structure. The principal considered the innovation to be well accepted by the Chinese language team and decided to restructure the school leadership team in order to extend the innovation to other subjects. He promoted the IT team leader (project coordinator for the e-learning pilot project) to become the Curriculum Development (CD) team leader and all e-learning initiatives would be led by the CD team. While the Chinese language team would still have their regular meetings and continue to integrate the planning of e-learning into these regular meetings, the principal and the pilot project coordinator would no longer take part in these meetings on a regular basis. According to the project coordinator, the demonstration-discussion-collaboration-observation-reflection model of team meetings continued in the Chinese language team as the project teams members were already well-trained and could act as "seeds" of change to provide support and guidance to those novice to this approach. The principal also shifted his focus to overseeing the work of the CD team in realizing his broader e-learning vision. In Year 4, the main mission for the CD team was to stimulate e-learning implementation in Mathematics, using similar organization structures and interaction mechanisms as in the Chinese language TTMs developed during the e-learning pilot project.

At the project level, the core teams and regular meetings ended, and there was no more joint school interactions related to e-learning. The six school leaders were all pleased with what had been achieved in the project and there was no perceived need for further coordination as the project was successfully completed. To our knowledge, the school level architectures for e-learning (organizational structures and interaction mechanisms) in the other five schools were no longer operational.

What and how did School B learn?

At the surface, the pilot project coordinated by School B had similar architectures for learning in having core teams and monthly meetings. However, a closer inspection shows stark differences in all the key aspects when the finer details are examined. At the project level, the core team comprised the school principals and project coordinators from the five participating schools and the software development team representative (note the absence of any language teacher on the team). The monthly meetings of the project core team were centered

around communication with the software developer on platform functionalities and technical improvement. There were no structured interactions between the teachers across the five schools, except for an annual "dissemination and award presentation" event during which the teachers from each school presented their "good practices" to other teachers. However, there were minimal interactions among teachers during these events.

At the school level, the main opportunity for teachers to learn was attending technical workshops provided by the software developer and the IT team members within the school (only one such workshop in Year 3). The school-based meetings were organized on a need basis and not regular, and the interaction focus was on how to improve the functionality and user-friendliness of the platform, and not pedagogy. There were only a total of three meetings in Year 3. There was little opportunity for teachers to discuss pedagogical issues or concerns, or to make sense of how this e-writing platform could help students to advance their language competence. Interviews with the teachers at the end of Year 3 revealed that they did not have much advancement in their understanding of the concept of "process writing", although this was what the e-writing platform was supposed to support as indicated in the project proposal submitted to EDB.

In Year 4, the entire set of organizational structures and interaction mechanisms described above disappeared at both the school and the project levels. The "architecture" in this case did not result in bringing about much learning even during the funding period. There were in fact little intentional efforts to bring about professional or organizational learning, as the nature of the pilot scheme was simply perceived as the development of an educational software for students.

What and how did School C learn?

There were strong similarities between the principals in School A and School C in how they led the project within their own school. Both emphasized the importance of building a learning culture and a shared vision among teachers through teacher co-planning, peer lesson observations and providing feedback to teachers. The school level learning architecture in School C had a rather sophisticated structure. Principal C decided to change the leadership structure for e-learning promotion in the school from one e-learning team to three core teams each with a specific focus: IT, curriculum development and learning resources, in order to lead the e-learning pilot project more effectively. These three teams met regularly to deliberate on implementation decisions in the school. Teachers in the school met regularly to conduct co-planning, lesson observation and reflection meetings, with support from the core team members as needed. The principal took part in lesson observations regularly.

The major difference in terms of learning architecture between School A and School C was at the project level. There was a joint-school principals' network and a teachers' network for the project. The latter also had specialized sub-networks under it for IT coordination and for the different subject areas. There were also regular meetings between the principals' and the teachers' networks to exchange ideas and concerns, and to explore solutions. During these meetings, the teachers would report the problems identified by the teachers' network to the principals' network. The principals' network then held meetings to discuss the issues raised, which might concern administration, resources, technology, or pedagogy, and come up with solutions to feedback to the teachers' network. These joint network meetings provided a strong communication channel between teachers and principals, which helped to provide timely support during the process of project development and implementation, and strengthened teachers' commitment and trust in the project.

The online SELTAS platform also played a crucial role in supporting the communication channels, particularly among teachers in different schools. Teachers uploaded to the platform ideas and problems they met in teaching. Alert emails will be sent to teachers in the network to invite contributions of ideas to the problems. The platform was organized into different areas, such as learning resources, curriculum management, technical concerns, etc., based on the decisions of the teachers' network. Table 2 summarizes the different elements of the architecture for learning available to the principal and teachers in School C, which scaffolded cross-school interactions at principal and teacher levels, and cross-level interactions within and across schools.

Table 2: Architectures for Learning in School C at school and project levels in Year 3

Level	Within level		Cross level	
	Within school	Cross school	Within school	Cross school
School	* Regular support and sharing across the three core teams	* Monthly Principal meetings * Monthly IT core team meetings	* Regular core team meetings * Biannual teacher professional development (TPD) days	* The principal and teachers in School C would provide support to colleagues in the network as needed
Teacher	* Co-planning and lesson observation * Reflection meetings	* Frequent Interactions on the SELTAS platform	* Regular lesson observation by principal and core team members	* IT and pedagogical support to partner schools

Given the rich and various structures and mechanisms available through the architecture for learning established in this project, it is not surprising to hear enthusiastic reports from teachers in School C about their learning gains through the e-learning pilot project. Learning gains reported include: changed understanding about the role of ICT in teaching and learning, greater willingness to try new things and to share their innovative practices within the project network, expanded capacity in lesson planning through having access to "pools" of references and resources constructed by teachers in the project network. Some reported that they could see how teachers' pedagogical practices were influenced by the cultures in their respective schools, and that they had broadened their horizon through learning within the network. Some teachers mentioned that they were initially unsure about the benefit of the project, but gradually developed their own understanding and ownership as they started to interact with other teachers and tried new practices in their classrooms. Some core team teachers felt that they had advanced in their knowledge of how to manage curriculum development, and how to stimulate, sustain and scale pedagogical innovations. The project coordinator even mentioned in the end of Year 3 interview that there should be reciprocal dynamics at the system level for scaling innovations!

As the e-learning pilot was only the latest of several collaborative projects that the ten SEN schools engaged in since 2006 to realize their goal of finding better ways to implement the idea of universal designs for learning for SEN students, the principals were actively engaging in explorations of how to extend the project beyond the funding period during the third and final year of the e-learning Pilot Scheme. In Year 3, an additional SEN school joined the project as an unfunded network partner (courtesy of the 10 project schools). In Year 4, the network structures and mechanisms remained largely unchanged. The SELTAS platform was even more heavily used and served to act as an archiving and knowledge management platform for the curriculum, lesson design and assessment artifacts generated and shared by the teachers. The e-learning innovations developed during the previous three years were not only sustained, but were further extended. The network had also succeeded in getting further sponsorship to develop a student portal extension to SELTAS in order to increase the range of e-learning possibilities for students.

Discussion and conclusion

All of the three e-learning pilot schools in this study achieved what they set out to accomplish as set out in the project proposal they submitted, but the nature of these "innovations" were very different. We set out to look for evidence of scalability after the pilot scheme ended, and we found that the scalability beyond the funding period was strongly linked to the architecture for learning the schools and the projects constructed. Structures and mechanisms among teachers and among principals across schools were important to support learning, and cross level interaction between principals and teachers contributed much to self-organized adjustments to the administration, routines and support in the school in response to the problems teachers encountered in the implementation. Organizational structures and interactions set up for project implementation may not lead to learning unless professional and organizational learning is intentionally planned and recognized as a crucial goal for implementation success. In fact, the architectures for learning that the schools and projects constructed were greatly influenced by the nature of the innovation as perceived by the change leaders. Where professional and organizational learning was not considered as the primary goal and pathway to success for the innovation, as in the case of School B, the architecture for project management would not lead to learning, and it is conceivable that the innovation did not sustain. The innovation in School C not only scaled in Year 4, the entire network it coordinated further prospered. School A demonstrated scalability of its innovation through strong leadership of the principal, but was not able to benefit from broader opportunities as the innovation network no longer existed.

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Acknowledgments

Short Papers

Technology-Supported Dialog as a Bridge to Developing Individual Argumentive Thinking and Writing

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Abstract: We describe the rationale, implementation, and outcomes of a multi-year program featuring electronic dialog as a tool in developing both discourse skills and individual argumentive thinking and writing in middle-school students. Its theoretical roots lie in the sociocultural tradition, in particular Vygotsky's view that the inter-mental with practice becomes interiorized and transformed into the intra-mental. We report on the gains observed among successive cohorts, relative to close comparison groups who engaged in non-dialogic whole-class discussion. Gains are seen both in dialogic argumentation and in individual written argument, specifically with respect to counterargument and the use of evidence.

Keywords: argumentation, technology, discourse, dialog, writing, reasoning, middle school

Introduction

The last decade has seen a notable expansion of attention to argument skills as an educational objective, reinforced by the US Common Core Standards emphasis on non-fiction writing and reading, and, within science, by the US Next Generation Science Standards emphasis on scientific practices, in particular argumentation. Neither set of standards, however, specifies how mastery of argument skills is best achieved. We describe a multi-year program featuring electronic dialog as a tool in developing argumentive thinking and writing in middle-school students. The program rests on the view that core intellectual skills such as argumentation must be developed in a context of rich content but are sufficiently important to warrant dedicated attention, rather than being subordinated entirely to subject matter content goals, where they risk neglect.

Rationale

We regard dialogic argumentation as a productive vehicle for developing both individual and dialogic argumentive competencies on several grounds. One is the close connection between an individual argument as a product and dialogic argumentation as a process (Billig, 1987). Another is the developmental origins of dialogic argumentation in everyday talk. A third is the ability of dialogic argumentation to provide the "missing interlocutor" (Graff, 2003) that often leaves students' expository writing devoid of purpose.

Our approach is consistent with the sociocultural tradition of Vygotsky in taking the everyday social practice of dialog as a starting point and pathway for individual development: The inter-mental with practice becomes interiorized and transformed into the intra-mental. A dialogic approach argumentation has ancient origins with Socrates and Plato. We draw on the contemporary philosophical work of Walton (1989), who identifies two goals of argumentation: to secure commitments from the opponent that can be used to support one's own argument and to undermine the opponent's position by identifying and challenging its weaknesses.

Skill development requires sustained, dense practice in rich environments that require those skills and values. It requires both a supportive community and the strengthening of individual skills and understanding, and hence is not quickly achieved (Kuhn et al., 2013). In contrast to approaches emphasizing explicit instruction as the key tool in developing critical thinking and writing, our approach is experiential in its pedagogical emphasis and microgenetic with regard to research methodology. By observing students engaged in technology-supported guided practice, we believe we seek to gain insight into what develops and how.

Overview of method

Our initial work documented that young adolescents engaged in argumentation concentrate on exposition of their own claims, essentially ignoring the opponent's position. Thus, the initial goals of our program are to encourage attention to the other's position and to enhance ability and disposition to address it, the objective being to weaken it, or in other words, to engage in counterargumentation. Our focus then shifts to use of evidence to strengthen and weaken claims. By securing answers to their own self-generated questions on the topic, students contribute to a set of evidence that plays an increasing role in their argumentation. Students ask questions so as to create a need for the information they acquire. They see how such information could be useful in achieving their discourse objectives, and then we assist them in securing it.

The recurring sequence of activities and their objectives are summarized in Table 1. The cognitive goals are not strictly sequential in order and rather are visited and revisited multiple times with new and gradually more complex ideas and topics. The core activity is one in which students use chat software to conduct electronic dialogs on a social issue (Fig. 1). They begin with topics close to their own experience, e.g., Should a misbehaving student be expelled or given a second chance, and gradually move on to topics of wider scope, e.g., Should organ sales be allowed. See Kuhn et al. (2016) for further details.

Table 1: Summary of curriculum activities and associated cognitive goals

Curriculum Activity	Cognitive Goal
Generating reasons	Reasons underlie opinions. Different reasons exist for the same opinion.
Elaborating reasons	Good reasons support opinions.
Evaluating reasons	Some reasons are better than others.
Developing reasons into an argument	Reasons connect to one another and are building blocks of argument.
Examining and evaluating opponents' reasons	Opponents have reasons too.
Generating counterarguments to others' reasons	Reasons can be countered.
Generating rebuttals to others' counterarguments	Counters to reasons can be rebutted.
Supporting [and weakening] arguments with evidence	Evidence can strengthen claims. It can also weaken claims.
Contemplating mixed evidence	The same evidence can be used to support or weaken different claims. The same claim can be supported or weakened by different pieces of evidence
Conducting and evaluating two-sided arguments	Opposing positions must be weighed in a framework of alternatives and evidence.
Constructing a [written or oral] individual argument	An individual argument can be constructed from a dialogic argument.
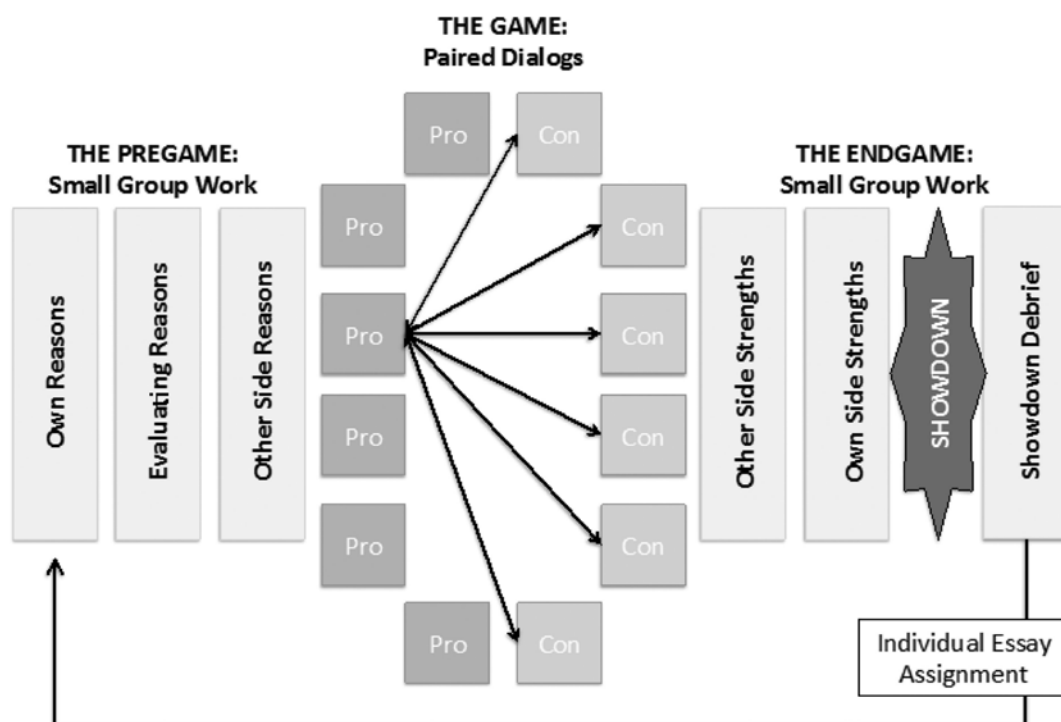
Figure 1. Topic workflow from pregame to final essay (from Kuhn et al., 2013).

Discourse is electronic to facilitate reflection on it. Students work in same-side pairs to promote externalization of and reflection on their thinking, with each pair conducting electronic dialogs with a series of opposing-side pairs. Over 13 class sessions devoted to a single topic, same-side team work precedes and follows

the dialogs. The sequence culminates in a whole-class "Showdown" debate, debrief, and individual position essays (Fig. 1). The major way we support students' thinking is by externalizing it, making it more visible. Doing so increases awareness of their own and others' thinking, a first step in enabling them to reflect on it, and, in so doing, to enrich it. The visible transcript of the dialog allows students to review and reflect on what has been said. This feature stands in striking contrast to face-to-face dialog, where the spoken word disappears once it is uttered, challenging memory capacities.

Because the pair must agree in advance on what to communicate to the opposing pair, participation in reasoned discourse is doubled (both verbal within the same-side pair and electronic between opposing pairs) and encourages metacognitive planning and reflection (since the pair must reflect on the opponents' statements and debate what to say in return). Other activities based on the dialogs function as additional tools of reflection. For example, students are asked to identify the major arguments and their counterarguments and rebuttals, as well as relevant evidence. These summaries remain available as resources during preparation for the final Showdown and the Showdown itself, as well as the adult-led debrief analysis that follows.

That activities center around peer interchange, rather than whole-class, teacher-directed talk, promotes students becoming accountable to one another, as members of a community with evolving group norms. Students are constantly on call and cannot assume the passive role of audience. These evolving norms must be constructed within the group and gain acceptance by its members, with risk of criticism for violating them. Claims must have reasons and reasons must stand to the challenge of arguments and evidence that can weaken them. Shared understandings evolve regarding acceptable counterarguments and what counts as evidence.

Results

Our assessment of outcomes is based on 12 middle-school classes who participated twice weekly for two to three years. Comparison classrooms participated in a parallel twice-weekly class taught by school faculty. This class was equivalent in time and work investment but followed a more traditional whole-class format, plus writing assignments, but without the pair dialogs, electronic discourse, or structured debates of our curriculum. Initial and final assessments of these classes as well allowed for close comparison.

At annual assessments a pair who held opposing views on the assessment topic (capital punishment, which was not part of the curriculum) conducted a dialog in writing. These were divided into idea units and each classified according to whether it "countered" the opponent's immediately preceding statement in either of two ways —as a counter-alternative, i.e., one that opposes the statement by proposing an alternative argument, or as the stronger counter-critique (or direct counter) that opposes the statement and directly critiques it.

Proportions of dialog statements classified as counterarguments rose with each yearly assessment among the participating group but not the comparison group (Crowell & Kuhn, 2014). (See Figures 2 and 3.) As shown, it is mainly the simpler counter-alternative arguments that become more prevalent during the first year, while counter-critiques do not rise until the second year. Least overall gain appears during the third year. Yet, when these gains are broken down by initial skill level, the one third of the experimental group that showed least skill at the initial assessment continue to improve during the third year, indicating the program continues to be of benefit to them. Indeed, even this initially least able group reached a proportion of direct counterargument of almost 50%, almost equal to that of their peers who began with more initial skill. These findings are important in establishing not only that the curriculum works but does so very well for low-ability students.
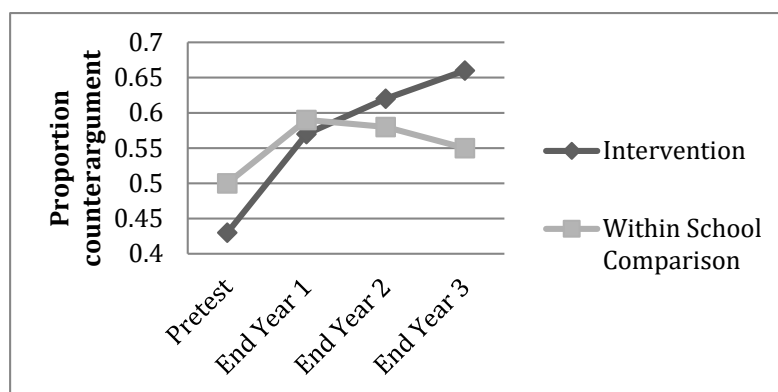
Figure 2. Mean proportion counterargument use by group and time (from Crowell & Kuhn, 2014).
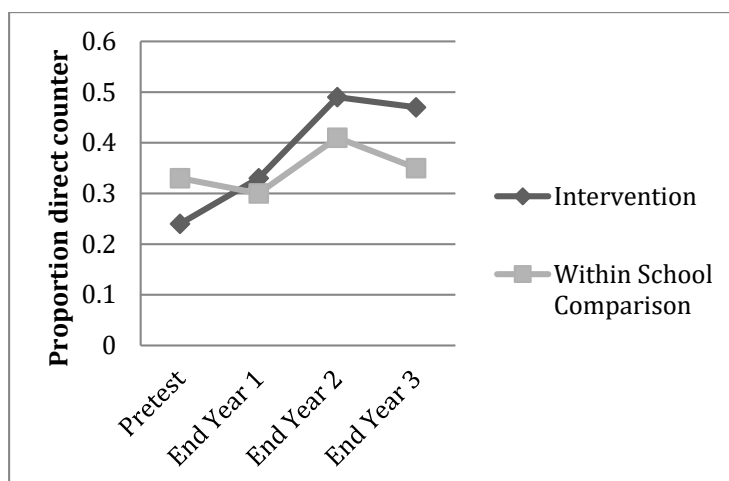
Figure 3. Mean proportion counter-critique use by group and time (from Crowell & Kuhn, 2014).

We also saw gains in students' evaluation of arguments and in their construction of hypothetical two-sided dialogic arguments (Kuhn et al., 2013), and the outcome measure of greatest interest to educators, students' individual argumentive essays. We administered at each assessment point a writing assignment on a topic not part of the curriculum. We kept the topic constant over time, to be able to more precisely gauge students' gains. Like the dialogic assessments, this assessment was also administered to the comparison classes.

At the pretest one third of both groups wrote essays that addressed both sides of the issue (whether teachers should receive experience-based or equal pay). At the end of year 1, two thirds of the experimental group did so, with no significant change in the comparison group, and at the end of year 2 this percentage rose to 79%, again with no improvement in the comparison group (Kuhn & Crowell, 2011). Further development toward an integrative stance (that includes negatives of preferred position or positives of opposing position) did not occur until year 3 and only in the experimental group.

Conclusion

Argument as core curriculum requires not only new approaches but a vision and commitment on the part of educators, especially when competing, more traditional objectives infringe on it. Our findings support the view that its place as core curriculum is productive and thus justified. The group norms regarding intellectual discourse that we observe evolve during our curriculum are at first confined to this special context, but hopefully in time become familiar enough that students begin to recognize these standards as a powerful and valued mode of discourse observable far beyond their classrooms, one that they are capable of participating in fully, as citizens and in all their individual pursuits.

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The Influence of Question Wording on Children's Tendencies to Provide Teleological Explanations for Natural Phenomena

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Abstract: Young children often provide teleological explanations for Entities and Phenomena in the natural world; stating, for example, that snow is for making snowmen or nighttime is for going to sleep. However, research supporting this stance has employed questions that could be considered to be teleologically-leading, suggesting a partially inaccurate view of children's tendency to provide teleological explanations. This paper compares a teleologically-leading treatment (*what is X for?*) with an open-treatment (*why is there X?*), finding that the leading-treatment resulted in significantly more teleological explanations that the open-treatment. This suggests children's proposed bias to provide teleological rationales about the natural world may be being overestimated.

Keywords: natural phenomena, science education, teleological reasoning, young children

Introduction

Teleological explanations are those that imply a natural object or phenomenon exists for a specific purpose (Kampourakis, 2014; Kelemen, 1999a, 1999b). In relation to science education about the Natural World the use of teleological explanations can be inappropriate and problematic as the focus is placed upon perceived outcomes or goals rather than causal accounts. Teleological reasoning is considered by some to be a major barrier to understanding evolution (Kampourakis, 2014) and a debilitating factor which restricts scientific reasoning (Hanke, 2004). However, there is an argument that the appropriateness of a teleological explanation depends upon the context in which it is used and the subject to which it relates. In these situations certain teleological accounts could be considered valuable learning heuristics (Ruse, 1989; Zohar & Ginossar, 1998).

Considering the appropriateness of a specific teleological explanation rests upon the type of teleology employed. The commonly discussed construct is design-teleology: that a topic has been designed or created for a specific purpose (Kelemen, 1999a, 1999b), if the creator was supernatural this could be considered to be religious-teleology. Teleology can also be conceptualised as functional-teleology, for example, appropriate functional explanations for Natural Organism appendages (Ayla, 1970), or as relational-teleology, a topic is not designed for something but rather subjectively used to do something (Ojalehto, Waxman, & Medin, 2013). While the type of teleology used is key to the appropriateness of the explanation, the focus of this paper is simply children's propensity to provide teleological rationales, regardless of their perceived relevance. In this paper these four constructs of teleology are collectively referred to as teleological explanations.

The levels of children's teleological thinking vary between ontological categories, due to the debate around if children are selective (provide teleological explanations for parts of Organisms and Artefacts) (Kampourakis, Palaiokrassa, Papadopoulou, Pavlidi, & Argyropoulou, 2012; Keil, 1994) or promiscuous (maintain a teleological stance for all ontological categories) (Kelemen, 1999a, 1999b) in their application of teleology. However, in some form teleological explanations dominate the scientific discourse of children age 4- to 9-years old, although their use decreases with age (Kampourakis, 2014; Kelemen, 1999b).

A key figure in this field is Kelemen. In an often-cited paper Kelemen (1999a) asked 4- and 5-year-old *what is X for?* in relation to several topics of Organisms, Natural Objects and Artefacts. The results indicated that the majority of children displayed a strong promiscuous tendency to provide teleological explanations for all ontological categories, with 57% teleological answers for Organisms, 88% for Organism parts 67% for Natural Objects, 58% for Natural Object parts, 65% for Artefacts and 80% for Artefact parts (means taken from graphs). However, there is a possibility that the question wording, *what is X for?* could be a teleologically-leading question, which may have inadvertently placed certain demand characteristics (Orne, 1962) upon the child leading them to provide a higher level of purposeful responses. This notion requires further investigation as the question wording used may have resulted in an overestimation of children's predisposition to provide teleological explanations.

Other studies have used different techniques to understand children's propensity for teleological reasoning. Kelemen (1999b) gave children in US Grades 1, 2 and 4 multiple choice questions (MCQ), for four Organisms and four Natural Objects, each containing a social or self-serving teleological and a scientific option.

Across the age range 70.5% of 1st Graders gave teleological responses for Natural Objects and 53.0% for Organisms parts; 2nd Graders responses were 75.0% for Natural Objects and 65.5% for Organisms; 4th Graders responses were 56.5% for Natural Objects and 59.5% for Organisms. However, dichotomous MCQ could be problematic as they may not measure what the respondent believes, merely which answer they think is more correct, or which option they dislike the least. This concern is shared by Kampourakis et al. (2012, p. 283) who maintain that the use of MCQ may not have provided a comprehensive view of children's actual beliefs. To explore this they used similar methods to Kelemen (1999b) but instead of MCQ, used open-ended questions on a written survey. Their findings support a selective application of teleology, not a promiscuous application; Natural objects traits received 17.2% teleological responses for Pre-schoolers, 9.0% for 1st Graders and 4.7% for 2nd Graders. Organism traits received 27.4% teleological responses for Pre-schoolers, 26.68% for first graders and 21.48% for Second graders. The difference in levels of teleological answers in the studies by Kelemen and Kampourakis et al. suggests that assessment method, MCQ or open-ended questions, could influence children's tendency to choose or provide teleological explanations. Although this finding is only relevant to Natural Objects, Organisms received similar levels of teleological answers in both papers, perhaps because functional rationales could be used to explain the appendages of Organisms. Therefore, questions investigating organism parts could be leading, as a functional-teleological explanation is a plausible and scientifically acceptable response.

It should be noted that Kelemen (1999a) is not the only researcher to use what could be considered questions that lead to, or require, a teleological answer. Keil (1994) used MCQ options in the form of *X helps Y* and *it is better for X to have Y*. Other abstracted examples of open-ended and MCQ include, *why do these X's do Y?* (Polling & Evans, 2002), *why does Y have X?* (Kampourakis et al., 2012), *why do you think X had Y?* (Kelemen, 1999b). The latter two question stems being particularly difficult to answer for Organism appendages without using functional-teleology (e.g. an eagle's wing can be considered to be for flight). These possible leading-questions share a similar stem, either the question is asking for the purpose of a certain topic (X), or for the purpose of an appendage (X) of a certain topic (Y). These two questions stems, *What is the purpose of X* and *What is the purpose of X for Y* can be further combined into *what is the purpose of X,* or simply *what is X for?* This generalised question stem, of what may possibly be a teleologically-leading question, is the same as the one used by Kelemen (1999a). Therefore, it provides a suitable example of a leading-treatment.

The purpose of this study was to investigate the hypothesis that question wording influences children's responses to questions about scientific phenomena, with a leading treatment (*what is X for?*) predicted to result in more teleological responses than an open treatment (*why is there X?*). Furthermore, it was hypothesised that as children's age increased the levels of scientific responses would increase, however it was not clear how age would interact with question format.

Method

Participants
The participants were 66 primary school children, aged 68- to 104-months-old (5- to 8-years-old) ($M = 85.59$, $SD = 10.84$, Female = 34). Participants were equally split between Year 1, 2 and 3, no child was considered to have English as an Additional Language or Special Educational Needs.

Procedure
The study used a repeated-measures design, the two levels of the question wording variable were the leading-treatment (*what is X for?*) and the open-treatment (*why is there X?*). Children received five of each question format across ten topics of Natural Phenomena. Piloting was conducted to find appropriate topics which children recognised and could articulate a response. The topics used, following piloting, were: Day, Darkness, Light, Night, Rain, Rainbows, Storms, Snow, Waterfalls and Waves. The topics were fully counterbalanced across treatment type to avoid influencing the main variable. Children were randomly assigned to treatment groups (leading-treatment 1st or open-treatment 1st).

Children took part in structured individual interviews, in a shared space outside of the main classrooms. All interviews began with a short drawing to settle the child and act as an icebreaker. Following this, participants received either their five leading-questions or open-questions, depending upon treatment group. If a response was unclear the probe *can you tell me a bit for about Q?* (Q being the unclear statement) was used to elicit more information. If a child declined to answer, or suggested they did not know, the interviewer moved to the next question. After the first set of questions the participant played another round of the drawing game, before completing the interview with the remaining five leading- or open-questions.

Measures

To investigate the influence of question wording children's explanations were transcribed and coded as either a teleological or a scientific response; answers consisting of non-sequiturs, descriptions and 'don't know' responses were removed for analysis. The coding rubric is outlined in Table 1. A tenth of the data, 66 responses, were coded by a second coder, calculation of Cohen's K (K = .885, p < .001) revealed a high level of agreement.

Table 1: Coding rubric for categorising explanation type

Type of response (score)	Explanation	Example
Teleological explanation (0)	The existence of the topic is referred to by invoking a purpose, implying that the topic aids another entity	Night is "for making the sky dark so we can have a little sleep" Rain "is for keeping all the plants, grass and flowers healthy"
Scientific explanation (1)	The existence of the topic is explained via a, simplified, causal explanation. However, does not have to be scientifically correct. The topic is not imbued with purpose	"when it rains and suns at the same time it makes, it makes a rainbow" When "it's very cold the rain comes down and it freezes and becomes snow"
Other (uncoded)	Non-sequiturs, descriptive answers, 'don't know' and non-responses	"my favourite rainbow colour is red" "when it's stormy the floor gets wet"

Results

Across the two treatments, 72 out of 660 responses were coded as 'other', 456 (69.0%) were coded as teleological answers and 132 (20.0%) as scientific. Removing the 'other' data resulted in a split of 77.6% teleological answers and 22.4% scientific responses. Separating the data by question wording suggests a strong influence of question wording, with 92.12% of the leading-treatment's responses being teleological answers compared to 68.18% teleological explanations for the open-treatment.

A two-way ANCOVA was conducted, with the independent variable of question wording (leading- and open-treatment), and the dependent variable of summed scores for the five leading-questions and five open-questions. Teleological responses scored 0 and scientific answers scored 1; therefore, each treatment has a possible summed score of 0-5. The covariate was mean-centred age in months. Means are displayed in Table 2.

Table 2: Table mean scientific responses by treatment type

	Total (n = 66)	Leading-treatment 1st (n = 33)	Open-treatment 1st (n = 33)
Treatment	Mean score as % of scientific responses (SD)	Mean score as % of scientific responses (SD)	Mean score as % of scientific responses (SD)
Leading-treatment	7.88 (13.979)	7.88 (15.763)	7.88 (12.185)
Open-treatment	31.82 (30.377)	26.06 (26.685)	37.56 (33.074)

The ANCOVA showed a significant effect of question wording upon response type, F (1, 63) = 44.579, $p.$ < .001, η^2 = .414, with the leading-treatment resulting in a significantly larger number of teleological responses than the open-treatment. The covariate of age in months was a significant predictor of response type F (1, 63) = 4.402, $p.$ < .040, η^2 = .065 but did not interact with question wording, F (1,63) = 0.013, $p.$ > .05, η^2 < .001, confirming that, regardless of treatment type, children provided less teleological explanations with age. Checks on the counterbalancing confirmed there was no significant influence of treatment order F (1, 63) = 4.402, $p.$ > .05, η^2 = .065 upon participant score, so randomisation was successful. Furthermore, there was no interaction between treatment order and question wording, F (1, 63) = 2.592, $p.$ > .05, η^2 = .040. When receiving the leading-treatment first, children were not primed to provide teleological explanations for their second set of questions using the open-treatment, nor when receiving the open-treatment first were children primed to provide scientific answers.

Conclusion and implications

The results confirm that children (aged 5- to 7-years-old) have a strong teleological bias to provide purposeful explanations for Natural Phenomena. With regards to this debate around if children employ promiscuous- or

selective-teleology these results supports the former. When receiving the open-treatment 68.18% of children's explanations were teleological answers, a score similar to the findings of Kelemen (1999b), 56.5-75.0% for Natural Objects, than to those of (Kampourakis et al., 2012), 4.7-17.2 %. However, it should be noted that this study is limited by only investigating topics of Natural Phenomena.

In relation to the influence of question wording, the results confirm the hypothesis: the leading-treatment (*what is X for?*) resulted in children giving predominantly teleological answers and the open-treatment (*why is there X?*) provided less teleological and more scientific responses. Consequently, research employing leading-question may have inadvertently placed demand characteristics upon their participants, leading to a higher level of teleological explanations. This result does not undermine the findings of Kelemen (1999a), and others cited above. However, it does suggest an overestimation of children's teleological tendencies; indicating that children may be more scientifically competent in their explanations than the literature suggests. Further research would be needed to ascertain the influence of question wording for different ontological categories, although this may be problematic with Organisms or Appendages where functional-teleological explanations could be considered appropriate. While children's tendency to provide teleological explanations decreased with age, supporting Kelemen's (1999b) and (Kampourakis et al., 2012) findings, the influence of question wording did not diminish: all ages were equally influence by treatment type. Therefore, the finding that question wording can result in an overestimation of teleological tendencies may be applicable to a wider age-range.

The main implication arising from this study is the need for research assessing children's teleological or scientific explanations to avoid the use of teleologically-leading questions. However, an educational implication would be that if young children advocate less teleological explanations for Natural Phenomena that previously indicated, they may be more susceptible to the teaching of causal accounts. This conclusion forms part of a larger research project which investigates how question topics within the same ontological category affect children's responses. It also analyses the type of teleological explanations to examine why children may be providing purposeful rationales. For example, are children using teleology to appropriately explain a function (functional-teleology), to suggest a topic has been designed for a purpose (design-teleology) or to propose a purpose for which a topic could be used (relational-teleology). While analysis is ongoing, initial results suggest that selection of topic and disregard for the type of teleology children are advocating may also lead to an overestimation of children's teleological tendencies.

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Acknowledgments

"*That's Your Heart!*": Live Physiological Sensing and Visualization Tools for Life-Relevant and Collaborative STEM Learning

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Abstract: Wearable technology and large-screen display systems show potential for helping learners engage in STEM in ways relevant to their daily lives, but it is important to understand how learning activities coupled with these tools can promote rich learning experiences. To advance these goals, our work utilizes a new genre of embodied technology tools for STEM learning—live physiological sensing and visualization (LPSV) tools, called BodyVis and SharedPhys—that display learners' physiological functions in real-time on a wearable, e-textile shirt and a large-screen display, respectively. We iteratively developed a set of learning activities to evaluate how these tools can support STEM engagement. Our findings show potential for LPSV tools to enable new forms of life-relevant and collaborative scientific learning experiences.

Keywords: embodied learning, STEM, physiological sensing, LPSV tools

Introduction

Recent advances in wearable technologies (*e.g.,* fitness trackers) enable new opportunities to make STEM learning less abstract and more relevant to learners' lives. However, to fully realize the potential of wearables for STEM learning, we must understand how learning activities coupled with these tools can promote meaningful learning experiences. We advance this understanding in the context of live (*i.e.*, real-time) physiological sensing and visualization (LPSV) tools that support embodied learning to promote life-relevant, collaborative STEM learning. LPSV tools integrate real-time physiological sensing and visual displays to promote learning about organ function, physical activity, and scientific inquiry.

Our prior work has focused on the design of two LPSV tools, BodyVis and SharedPhys (Figure 1a and c, respectively), to support body learning and engagement in scientific inquiry by visualizing wearers' live body-data (*i.e.,* heart and breathing rate) on an electronic textile (e-textile) shirt (BodyVis) and a large-screen display (SharedPhys). We have two high-level goals with our LPSV tools: (i) to help children understand and learn about the body and its connection to the physical world (*e.g.,* eating, exercise), and (ii) to use the body as a life-relevant platform to help children build general scientific inquiry skills (*e.g., Why does my heart rate increase before a test or during soccer practice?).* In this paper, we analyze data from several deployments with a common analytical lens aimed specifically at better understanding how LPSV tools can support life-relevant and collaborative STEM learning experiences for elementary-aged youth.

Our findings show that LPSV tools were relevant to our participants' daily lives as they connected their own organ functions (*e.g.,* heart and breathing rate) to their everyday physical activities, emotions, and social experiences. Additionally, learners engaged in collective observation, experimentation, and hypothesis generation as they interacted with our LPSV tools. Our contributions include (i) characterizing learning experiences children have with LPSV tools, and (ii) design implications for LPSV learning activities.

Life-relevant and collaborative learning technologies

Our goal is to leverage wearables to deepen learners' STEM engagement through supporting life-relevant, collaborative inquiry experiences. In life-relevant learning experiences, learners derive meaning relevant to their lives from acting and thinking like scientists (Clegg, Gardner, & Kolodner, 2010). Such experiences enable learners to connect science inquiry and learning to their own interests, passions, and lived experiences (Clegg et al., 2010). Two recent approaches to wearable learning tools illustrate the potential of wearables to support life-relevant experiences by investigating one's own physical and physiological data: (i) using fitness trackers for math analysis—*e.g.,* comparing sports, validating accuracy of fitness trackers, strategizing workouts based on statistical data analysis (Lee, 2015, Chapter 9) and (ii) exergaming for STEM learning and health knowledge (*e.g.,* Carter Ching & Schaefer, 2015). These approaches offer opportunities for learners to create and engage in new inquiries with data from activities in their everyday lives (*e.g.,* games, sports).

| **(a)** BodyVis | **(b)** BodyVis in action | **(c)** SharedPhys' Moving Graphs | **(d)** SharedPhys in action |
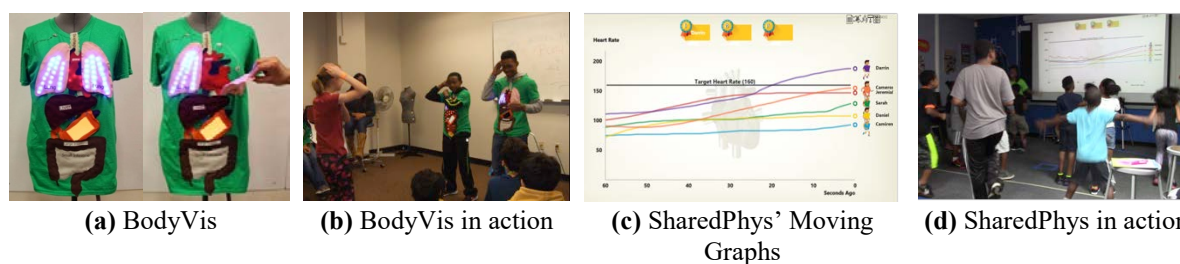
Figure 1. BodyVis (a) displays live physiological data on a wearable, e-textile shirt while SharedPhys' Moving Graphs (c) uses a time-series graph representation projected on a large-screen display. Some examples of high-impact activities include dancing with BodyVis (b) and doing jumping jacks with SharedPhys (d).

Our LPSV tools are designed to engage multiple learners in collaborative inquiry either in small groups (BodyVis) or in collective inquiry in whole classrooms (SharedPhys). Collaborative inquiry involves dialog among learners around scientific inquiry practices such as asking questions, designing experiments, collecting data, and developing claims (Chinn & Malhotra, 2001). Collective inquiry occurs when learners are engaged in scientific inquiry as a whole class, collaboratively negotiating problems and working toward a common goal (Lui, Kuhn, Acosta, Quintana, & Slotta, 2014; Lui, Slotta, & Cober, 2012). Embodied learning technologies can be effective for engaging learners in collective scientific inquiry. For example, embedded phenomena systems like *EvoRoom* and *HelioRoom* (Lui et al., 2014, 2012) allow learners to engage in small and whole group activities around asking questions, collecting data, and developing claims backed by evidence from the systems. To our knowledge, our approach to LPSV large-screen displays (Kang et al., 2016) is the first to support collective inquiry and STEM learning more broadly around body-data.

Design

We designed BodyVis and SharedPhys, along with associated learning activities, through an iterative process of participatory design with children and teachers. In this process, we first developed a wearable e-textile approach called BodyVis (Figure 1a), in which physiological phenomena (*e.g.,* heart rate and breathing rate) are visualized on wearable fabric anatomy allowing learners to gain a unique view of the internal body (Norooz, Mauriello, Jorgensen, McNally, & Froehlich, 2015). Next, to support whole-classroom STEM learning and scientific inquiry we developed SharedPhys (Kang et al., 2016). SharedPhys enables collection and analysis of data in real-time across multiple learners by visualizing real-time physiological data from up to six simultaneous users on a single, large-screen display. We focus on one of three SharedPhys designs called Moving Graphs, which transforms wearers' live body-data into line-graph form (Figure 1c). We designed LPSV learning activities through participatory design with (i) an intergenerational co-design team of children (7-11 years old) and adult researchers, as well as (ii) a cohort of 20 teachers in a STEM M.Ed. program. Children suggested competitions and games, while teachers suggested experimenting with our tools by brainstorming high- and low- impact physical activities that would affect the heart rate. Informed by these findings, we iteratively designed SharedPhys and LPSV learning activities to support science inquiry experiences. Our activities focused on having participants use LPSV tools to hypothesize and test physical activities that would lower and raise their heart and breathing rates. We discuss our session protocol in the next section.

Method

We conducted six BodyVis and six SharedPhys study sessions independently. Three of the six BodyVis sessions were reported in (Norooz et al., 2015); here we analyze only the three latest BodyVis sessions which were conducted with our new LPSV learning activities. BodyVis and SharedPhys sessions followed the same format. Each session was approximately two-hours long. Sessions were primarily conducted in out-of-school programs although one BodyVis session was conducted in a joint 2nd and 3rd grade private school classroom. In total, 61 children participated in BodyVis sessions (34 boys, 27 girls) aged 6-13, and 69 children (42 boys, 27 girls) aged 5-13 participated in SharedPhys sessions. Before sessions began, we randomly assigned participants to groups of 4-5 children. We then presented an overview of each respective tool and introduced the inquiry activity. Groups were given a brainstorming period to develop a set of high- and low-impact activities that would increase and decrease their heart and/or breathing rates, respectively. Groups recorded these activities on large notepads, then came back together to present their activities and hypotheses. As each group presented, two BodyVis volunteers, or six SharedPhys volunteers, tested the highest- and lowest- impact activities suggested with the respective LPSV tool. Following each hypothesis test, a facilitator guided a conversation about why they believed the body reacted the way it did.

All BodyVis and SharedPhys deployments were video recorded and researchers also took field notes. For the video analysis of each tool, we followed Chi's eight-step process (1997) using a mixed deductive and inductive approach. Based on observations of a single video, a single researcher developed an initial codebook for observing learners' collaboration (*e.g.,* ways wearers and non-wearers interacted) and life-relevant experiences (*e.g.,* indicators of linking experiences to everyday life, demonstrations of excitement and curiosity) for each tool. Two researchers then met and simultaneously coded a second video for each tool, concurrently updating the codebook. Finally, two researchers coded all videos independently, developed summaries, and then met to discuss and co-interpret the data. One researcher wrote a final summary.

Findings

We report findings related to life-relevance and collaboration for both BodyVis and SharedPhys sessions.

Life-Relevance. With both LPSV tools, participants referenced activities in their everyday lives (*e.g.* playing video games, eating, doing homework) to form their hypotheses of activities that would increase or decrease their heart rates. Each tool also fostered different forms of life-relevance. With BodyVis, participants explored how their emotions affected their physiology. For example, when lying down participants found that, contrary to their expectations, the wearer's heart rate actually increased due to the excitement of the activity. One after-school program regularly required children to reflect on their session experiences at home via a custom-built science inquiry app. Using the app, some participants made similar connections between their heart rate and emotions as they observed their heart rate during other activities: "*Watching the NBA summer league second game brought my heart rate down after running because less blood must be pumped when I am just sitting down and not stressing my muscles and lungs by breathing hard and also the fact that the game was just summer league and not NBA didn't stress me for my team to win.*" SharedPhys created a sense of life-relevance for participants in two ways. First, wearers felt a strong connection with the visualizations because of the live body-data and direct control of visualizations. This was apparent during the hypotheses testing, when both wearers and non-wearers instantly started moving fast (*e.g.,* jogging in place, doing jumping jacks) as soon as the graph was displayed. Second, learners demonstrated excitement and initiated engagement during the hypothesis testing competition where non-wearers cheered their wearer teammates by suggesting movements based on their observations and even mimicking those movements alongside the wearers.

Collaboration. With both BodyVis and SharedPhys, participants collaborated through brainstorming, discussing, experimenting, testing, and revising hypotheses. For activities with unknown outcomes, participants either discussed reasoning behind possible outcomes or placed the activity in an "unknown" category. For example, one group discussed how eating and digestion might affect their heart rate after a group member expressed feeling fatigued following a meal, while another thought their heart rate increased. LPSV tools also fostered unique collaborative experiences. With BodyVis, wearers and non-wearers engaged collaboratively in whole group discussions when wearers tested the groups' hypotheses and reacted to unexpected results. With each unexpected result, discussions—sometimes even debates—organically occurred among participants regarding the body's reaction. For example, one group hypothesized that an activity would decrease the heart rate, but in reality it increased. One group member reasoned that the activity involved more muscle activity than they originally thought: "[You are] *using so much muscles. Your head is going that way, your arms are going this way. So you're using too much energy.*" With SharedPhys, most verbal collaboration occurred among non-wearers rather than wearers (as wearers were quite focused on their tasks); however, wearers collaborated non-verbally through observation and physical mimicry. Tasked with making observations about wearers' data as it was visualized, non-wearers often collaborated by helping each other take notes or repeating things that were not originally heard. Wearers would observe and replicate the physical activity of the winning wearer during the hypothesis test competitions. As wearers focused more on their bodies, non-wearers noticed more of the affects of the wearers' physical activities on the Moving Graphs and provided guidance to reach the target heart rate (*e.g., "You're getting lower!" "Get some high knees in there!"*).

Discussion

Our goal was to understand the learning experiences children have with LPSV tools, particularly with respect to life-relevance and collaboration. Here, we discuss the interactions observed in our findings. BodyVis and SharedPhys show that LPSV tools can help learners connect their own everyday activities not only to step and mileage calculations (Carter Ching & Schaefer, 2015), but also to their own organ functions and systems (*e.g.,* heart/breathing rate, muscular system), and to social and emotional factors (*e.g.,* being nervous). Because learners could see body-data change in real-time, they may have been better able to connect the changes of other in-the-moment factors (*e.g.,* body movement, social and emotional context) to the changes they observed in their physiology. This suggests that LPSV tools offer learners opportunities that promote their consideration of the

multitude of physical and environmental factors that impact their bodies. Next, while prior work emphasizes collective inquiry around data analysis and development of claims backed by evidence (Lee, 2015; Lui et al., 2014), our analysis suggests that LPSV tools enable other aspects of collective inquiry—collective noticing, experimentation, and hypothesis generation. As participants observed the real-time changes in their heart and breathing rates, they began to collectively discuss other factors simultaneously affecting their bodies. Through these observations, learners generated new hypotheses to test and created new collective experiments (*e.g.,* observing effects of eating). Not only did they collectively discuss inquiry topics, learners often collectively acted. As they observed other groups testing activities, the most effective actions proliferated through the whole group— this sort of collective phenomena is enabled by the visibility of whole-body interactions and the shared, co-located context of the computer-mediated activities.

Wearable tools such as BodyVis require others to be in close vicinity of the wearer, which for some is an uncomfortable experience. LPSV tools and activities must therefore seriously consider learners' comfort and offer multiple types of wearer experiences (*e.g.,* ways to reduce spotlight on learners). Additionally, our analysis suggests LPSV tools have the potential to promote a deeper understanding of physiological concepts, beyond the cause-and-effect of physical activities on the body to social and emotional concepts.

Conclusion

Our work demonstrates the potential of LPSV tools—via the examples of BodyVis and SharedPhys—to enable new forms of life-relevant and collaborative STEM learning experiences. While we found that LPSV tools can support learners' collective observations and experimentations, more work is needed to understand the most appropriate learning contexts for their use and ways that they can complement more traditional, retrospective analysis of body-data (Lee, 2015). Our analysis points to several implications for learning activities with LPSV tools. First, learners need formal and informal time with the tools to play, explore, and delve deeper into inquiry and science content learning. Additionally, learners need opportunities to both *wear* and *observe* LPSV tools as different forms of engagement are promoted through wearer/non-wearer roles. Finally, learning contexts should be flexible to allow learners to try new activities and investigations.

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Acknowledgments

Managing Threats to Teacher Face in Discussions of Video-Recorded Lessons

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Abstract: Scholars and educators are increasingly enthusiastic about the potential benefits of video-based teacher learning. However, collaborative analysis of video is a complex social endeavor entailing numerous obstacles to learning, central among them face threats. In this study, we use linguistic ethnographic methods to investigate the implications for teacher face of using video in professional development, and the implications of teacher facework for their learning. We analyze 15 case studies of video-based discussions in school-based teacher teams, identifying and classifying face-threatening acts and the facework involved in responding to them. We then identify and analyze exemplary cases involving key facework strategies (face threat avoidance, face defending, and face correction), focusing on the ways these strategies opened up or closed down opportunities for learning. This study will contribute to our understanding of the interaction of social and cognitive dimensions of professional learning in general, and of teacher facework in video-based professional development.

Keywords: teacher learning, video-based professional development, face, linguistic ethnography

Video-based teacher professional learning

Research has demonstrated the potential benefits of on-the-job teacher collaborative discourse for instructional improvement (Little, 1982; Wilson & Berne, 1999). Particularly productive, studies suggest, is discourse that deprivatizes teaching practice (Bryk, Sebring, Allensworth, Luppescu & Easton, 2010; Little, 1990), involves rich representations of everyday classroom experiences (Gaudin & Chalies, 2015; Little, 2003; Van Es & Sherin, 2002), and engages practitioners in collaborative and reflective inquiry on problems of practice (Horn, 2005; Horn & Little, 2010; Lefstein & Snell, 2013).

In particular, educational researchers and teacher educators are increasingly enthusiastic about the potential benefits of video representations of classroom practice as tools in teachers' learning (e.g., Sherin, Jacobs & Philipp, 2011; Zhang, Lundeberg, Koehler & Eberhardt, 2011). Video-based discussions have the potential to cultivate collaborative teacher professional learning; make classroom practice public and explore theory in relation to concrete problems of practice (Darling-Hammond & Sykes, 1999; Stoll & Louis, 2007; Villegas-Reimers, 2003). However, video-based discussions entail exposure, which may be experienced as threatening by teachers who are concerned about accountability or are uncertain about the quality of their own performance. Above all, such exposure and the associated discussions of video-recorded practice inevitably lead to face threats.

While the efficacy of video-based learning has been demonstrated, the social processes through which teachers learn in such settings have yet to be thoroughly examined. This gap is particularly significant in light of evidence that teachers' work is governed by non-collaborative norms such as privacy, individualism and noninterference (Hargreaves, 1994; Little, 1990; Lortie, 1975). Video-based learning works against such norms, by exposing practice to scrutiny and critique in ways that other discussions, such as planning or consulting, do not. When colleagues watch a video of a teacher's practice, the video-recorded teacher has little control over what is exposed, relative to, for example, sharing a problem of practice through replay or rehearsal (Horn, 2010). In addition, video analysis often takes place in situations of complex power relations – among teachers, school management and external coaches (Lefstein & Snell, 2011). Thus, while video analysis has great potential for teacher learning, it is a complex social endeavor entailing numerous obstacles for learning. This study aims to shed light on this complexity through a linguistic ethnographic investigation of teachers' face-work in video-based discussions.

Framed by a socio-cultural perspective, in this study, we view learning in teacher teams as involving active participation in a community of practice (Wenger, 1999). We foreground social processes over individual ones, focusing on opportunities to learn, i.e., the ways access to professional knowledge is provided to participants, affording changes in participation and practice (Horn & Kane, 2015). Opportunities to learn are constructed through actions and interactions interpreted by members of the community. As an important facet of all social processes, facework is necessarily an important aspect of processes of social learning.

Face work

Face is one's positive image before others. It may be defined as the positive social value "a person effectively claims for himself" (Goffman 1955, p. 5) by presenting one's 'self' to others – and being perceived by them – in particular ways. A person may be presented through interaction as successful, or kind, or intelligent, or whatever social attributes are valued in that setting, and this is the image, or face, that the other parties to the interaction perceive. "Face, therefore, is precisely the conceptualization each of us makes of our 'self' through the construal of others in social interaction and particularly in verbal interaction, i.e. through talk" (Watts, 2003, p.124). Face is subject to constant, ongoing negotiation through micro-processes of talk and interaction. It is a changeable, unstable entity "diffusely located in the flow of events" (Goffman, 1955, p.7).

The work we do in social interaction to enable our self and others to construct and maintain face, is called *facework*. Facework is *'the actions taken by a person* to make whatever he is doing consistent with face. Face work serves to counteract ''incidents'' -- that is, events whose effective symbolic implications threaten face.' (Goffman, 1955, p. 12). Generally, the prevalent social norm is face maintenance, that is: people are expected to behave in a way that maintains both their own face (defensive orientation) and that of others (protective orientation), and prevents loss of face (Brown & Levinson, 1978). This is done by identifying potential face threats and working towards mitigating them, by: (a) avoiding them (e.g., changing the subject of discussion when it approaches a sensitive topic); (b) defending or protecting face when a threat is posed (e.g., by justifying a criticized behavior) and (c) reconstructing or correcting face when it was harmed (e.g., by apologizing or compensating through complimenting).

Nevertheless, in some social situations, face threatening acts are legitimate and even called for (e.g., news interviews). In other situations, such as video-based discussions, the observed teacher's face is on the line by virtue of the exposure of her practice and speech acts that are endemic to this activity, such as advice giving, evaluation and questioning (Copland, 2011). It is therefore important to understand:

1. What are the implications of using video for teachers' facework?

2. What are prevalent acts of facework in teachers learning from video: How do teachers: (a) avoid face threat? (b) Defend their own face? (c) Protect their colleagues' face? (d) Correct face loss?

3. What are the implications of such facework for teacher learning from video-based discussions of practice?

We explore these questions by analyzing 15 case studies of video-based discussions in school-based teacher teams.

Research methods

The data for this study was collected in the context of a large design-based implementation research project focusing upon teacher professional discourse and leadership. In the development year of this study, we worked with the coordinators of ten teacher teams in four schools in a large Israeli school district. These teacher leaders were responsible for facilitating weekly team meetings in their schools. In addition, they participated in a bi-weekly professional development workshop, in which they were provided with tools for fostering and enhancing the pedagogical discourse in their in-school meetings. We conducted participant observations in 118 of these team meetings over the course of the 2014-2015 school year; we audio-recorded these meetings, kept field notes, interviewed participating teacher leaders and recorded professional development workshops.

The data corpus for this study is comprised of 15 team meetings in which teachers discussed videos of classroom practice of an attending member of the team. One of the tools introduced in the program is protocols for video-based discussions. The protocols provide guidelines for structuring professional conversations, including delineation of roles, topics, sequences and ways of talking. The idea behind the protocol is to facilitate the development of productive norms for discussing practice and to counter restricting norms, such as normalization of problems of practice on one hand and hypercriticism on the other.

Data analysis and preliminary findings

To explore the implications of using video for teacher facework we analyze the data through both systematic coding of the episode and microanalysis. We identify face-threatening acts and classify them using categories based on Goffman (1955) and Brown and Levinson (1978), which we have further refined based upon our initial analysis (Table 1). The coding distinguishes between acts that threaten the face of the filmed teacher and are initiated by her ("self face") and face threatening acts that are initiated by others ("other face"). For example, the face of the filmed teacher may be threatened by criticizing the practice she exhibits in the video, but such face threat may have different implications depending on whether she criticizes herself or others criticize her. We then code these events (that involve face threatening acts) for facework that acts to: (a) avoid face threat; (b) defend

self or protect other's face when a threat is posed; and (c) reconstruct face when face was lost. Through this analysis we aim to provide a broad and nuanced account of different types of teacher facework in video-based discussions (Table 1).

Table 1. Initial coding scheme

	Self face	**Other face**
Face-threat avoidance	Change topic	
	Ignore	
	Withhold questions	
	Withhold disagreement	Withhold critique
Protect/defend face	Normalize	
	Ask reassurance, self-reassure	Reassure
	Attribute blame	
	Justify	
	Explain	
Correct (reconstruct) face		Apologize
	Compensate (e.g., self success story, self-provided solution)	Compensate (e.g., other's success story, self face threat, Compliment)
	Punish	
	Retreat	
	Humor	

To investigate the implications of different types of face work on teachers learning, we identify illustrative cases (based on the coding above) representing discourse dominated by:

1. Face threat avoidance. For example, in one team, video based discussions were limited to "appreciative feedback" in which participants highlighted positive aspects of the observed practice and avoided asking substantive questions, problematizing or criticizing practice.

2. Face defending and protecting. For example, in one case, teachers raised questions regarding a practice they observed in the video, whereby the teacher dictated the correct answer for the students to write. Following this potentially face-threatening questioning, the filmed teacher and her colleagues engaged in a series of acts (reasoning, blaming) that served to justify and unproblematize the teaching practice.

3. Face correction. For example, in one case a teacher was criticized for her failure to foster student talk in her class. The other teachers interrogated her, compared her practice to their own "successful" ones and gave her advice. She suffered face loss. Reconstructing her face she went into great length telling a heroic story of her own professional success.

Our analysis of these illustrative cases employs linguistic ethnographic methods (Rampton, Maybin & Roberts, 2015): we repeatedly listen to recorded episodes, transcribe them in detail, and brainstorm about what was happening and what we found interesting. We then use micro-analytic methods to analyze the sequential unfolding of selected events. Such analysis involves proceeding slowly through the recording, asking at each line, "What is the speaker doing?" "Why that, now?" "How does this turn at talk respond to what came before?" "What else might have been done here but wasn't?" etc. (Rampton, 2006). We focus on the ways different types of facework opened up or closed down opportunities to learn (Horn & Kane, 2015), such as identifying problems of practice, reframing them and deliberating about them, multiplicity of interpretations and alternative courses of action and considerations of the pros and cons of each of them. This analysis also incorporates data from field notes, coordinators interviews and the workshop recordings, in which participants shared their perspective on the video and the analyzed discussions.

Significance and contribution
This study will contribute to our understanding of teachers' video-based learning, and in particular to the social processes such learning entails. It will yield practical recommendations of ways to enhance the productivity of teachers' video-based learning. It will also shed light, more generally, on the implication of face threat and facework on professional learning.

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Fostering More Informed Epistemic Views Among Students Through Knowledge Building

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Abstract: Understanding students' epistemic views is critical for educators to understand how they work with ideas and knowledge. The present study explored how college students' online collaborative inquiry activities may inform their epistemic views. A mixed-method analysis revealed that students' online knowledge-building and inquiry activities were associated with the change of their epistemic views. When engaging in more productive group inquiry activities, a more sophisticated epistemic view conducive to continual idea improvement for knowledge advancement was more likely to develop among students.

Introduction

The demand for new knowledge and novel ideas to solve existing and emerging societal problems is increasing (Csikszentmihalyi & Wolfe, 2014; Drucker, 2011). Because ideas are essential for knowledge-creating and problem-solving and human beings are naturally capable of idea generation, it has become increasingly more important for educators to think about how to foster students' creative competency to generate and work creatively with ideas (Koh, Chai, Wong, & Hong, 2015). The educational challenge for knowledge innovation or creation, in particular, is how to maintain sustained effort for the improvement of ideas (Scardamalia & Bereiter, 2003; 2006). Traditional educational approaches tend to emphasize the importance of acquiring and accumulating knowledge from textbooks and instructors, while neglecting the more innovative part of transforming students into knowledge workers who can produce and improve ideas for their knowledge work (Scardamalia & Bereiter, 2015). Papert (2000) refers this educational phenomenon as "idea aversion" (i.e., dislike of ideas), and he further argues that typical learning environments are less likely to help students produce and work with their own ideas. Instead, they are designed for direct instruction for teachers (cf. Sawyer, 2004; 2011). Ideas initiated by students are treated with little value and are not much appreciated (unlike textbook knowledge that are favoured in most learning environments).Accordingly, students not encouraged either to dedicate themselves to pursue and materialize their ideas for the sake for knowledge advancement. To address this concern, the present study engaged students in the process of continual production and improvement of ideas.

Epistemological views concerning idea-centered knowledge work

The important role ideas played in a knowledge-intensive society may be best explained by Popper's (1972) three-world epistemology. Popper postulates three different forms of ontological reality to explain how the three epistemic worlds come into being. The three epistemic worlds are: (1) the natural/physical world (World 1), (2) the psychological world (World 2), and (3) the humanly-constructed conceptual world (World 3). In brief, World 1 refers to natural or physical reality, and can exist by itself with no human presence. World 2 considers reality as a mental state created in the human mind. It is a private world consisting of a person's personal thoughts and feelings, and the experiences of his or her perceptions and interpretations of World 1. In contrast, World 3 conceives reality as being constructed by man-made "ideas" as conceptual artefacts; these in turn give form to all other humanly-constructed, materialistic artefacts that further substantiate the existence of World 1. Popper especially highlights the important contribution of World 3 to human civilization that is caused by humans' exceptional imaginary capacity to work with and act upon ideas—ideas that are readily existent or emergent— and to transform them into feasible solutions and accepted knowledge for solving problems. Unfortunately, as argued by Bereiter (2002), traditional school education tends to value change in a student's mind-as-a-container in World 2 (e.g., by delivering knowledge from authoritative sources such as textbooks and teachers to the student), but neglect the importance of initiating students into a World 3, idea-centered, knowledge-building culture. The question of how to transform a World 2-oriented education that highlights knowledge acquisition into a World 3-oriented knowledge-building education remains an open pedagogical challenge.

Knowledge building pedagogy

Knowledge building is defined as a collaborative process that is focused on continuous work with ideas of value to a community (Scardamalia & Bereiter, 2006). Knowledge building can be characterized by three distinctive pedagogical design features: it is idea-centred, principle-based, and community-focused. First, building on

Popper's (1972) epistemological framing of World 3, knowledge building emphasizes the value and importance of ideas as epistemic entities for human knowledge construction, and considers idea improvement to be at the centre of all learning activities. Second, knowledge building employs a principle-based--rather than a procedure-based--pedagogical design to ensure the sustained improvement of ideas (Zhang, Hong, Scardamalia, Teo, & Morley, 2011). This design is very different from a highly structured, procedure-based instructional design for guiding classroom practices (Reigeluth, 2013). A pre-specified procedural design usually prescribes classroom activities in advance. Teachers are sometimes even required to carry out their instruction using certain teaching scripts (see Sawyer, 2004). In contrast, a principle-based approach only employs a number of guiding pedagogical principles to ensure maximum flexibility so that students can work adaptively with their self-generated ideas. For example, the knowledge-building principle of "idea diversity" highlights the fact that diversified ideas are essential to sustained knowledge advancement, "…just as biodiversity is essential to the success of an ecosystem. To understand an idea is to understand the ideas that surround it, including those that stand in contrast to it. Idea diversity creates a rich environment for ideas to evolve into new and more refined forms" (Scardamalia, 2002, p. 79). Third, knowledge building highlights community-oriented, rather than individual-oriented, knowledge practice. While ideas must be generated by individuals, continuous improvement of ideas relies on a whole community's collaborative effort. In particular, the quantity and quality of the ideas being enriched and refined are highly dependent on the effectiveness of social interactions in the community. Given the importance of fostering students' capacity to produce and work innovatively with ideas for knowledge work, the present study attempts to investigate (1) whether sustained idea improvement in a knowledge-building environment is related to a more constructivist-oriented, idea-centered World 3 epistemic view that is essential for creative knowledge work, and (2) whether the development of a constructivist-oriented, World 3 epistemic view is related to online collaborative inquiry activities.

Method

The participants in this study were 41 undergraduate students from a national university in Taiwan. The course was offered by the teacher-education program in the university to students who planned to teach about nature sciences and living technologies at primary schools after they graduate from university. The university is ranked as one of the top 10 universities in the nation. Over the past few years, supported by a grant from the nation's Ministry of Education, the university has been deeply dedicated to improving its course quality, with a reform preference toward transforming traditionally more didactic modes of teaching into more constructivist-oriented teaching practices. This reform movement created an opportunity for KB theory and technology to be introduced into this course as an alternative method of teaching and learning. The ages of the participants in this course ranged from 18 to 20. The duration of this course was 18 weeks.

The duration of the course was one semester. The main goal of the course was to help students develop a better understanding of the role of ideas in knowledge creation. To this end, they were guided to engage in the knowledge-building process, and as a learning outcome they were required to design some living technology products that could be used to enhance the quality of people's daily lives. To facilitate student learning, knowledge-building principles (e.g., "idea diversity", as discussed above) were employed to enable cycles of progressive idea improvement.

A pre-post survey on students' epistemic views, focusing on the nature of ideas and using the following open-ended questions, was employed: What are "ideas"? What are the criteria for a good idea? Why? Where do ideas come from? Can ideas be improved? If so, why can they be improved and how can they be improved? If not, why could they not be improved? As shown in Table 1, a coding scheme was developed, using Popper's (1972) conceptual framework of a three-world epistemology, to score students' responses to the above questions (Strauss & Corbin, 1990). If a response matched with a given coding category of an epistemic view (i.e., a World 2 or World 3 view), one point was given, with the maximum number of points for each of the two epistemic views being three. Inter-coder reliability, using the kappa coefficient, was computed as 0.90. In addition, participants' interaction patterns in the Knowledge Forum were analysed to provide a basic understanding of participants' online behaviour and learning processes (e.g., the average number of notes contributed, read, built on, etc.). T-tests were conducted to compare the differences between World 2 and World 3 epistemic views to see whether there is any change in students' views over time after they engaged in knowledge practice for a semester.

Table 1. Coding scheme based on Popper's conceptualization of ideas

Theme	Code	Example
World 3 view of ideas	Concrete object	After being put into practice, ideas can be presented in multiple forms such as a plan, a study, a real-life object, a commercial product, etc. (S24)

	Interaction with the world	Ideas can be formed from prior or present experiences in daily life.(S20)
	Group endeavour for advancing knowledge	Ideas are usually improved after idea interaction and group discussion. (S02)
World 2 view of ideas	Abstract concepts	An idea is a kind of abstract thought produced from thinking. (S19)
	Reflection	Ideas are one's personal points of view about something. (S10)
	Personal knowledge growth	Ideas can help improve one's intelligence. (S23)

Results

Epistemic view

As Table 2 shows, in the pre-survey, the participants' understanding of the nature of ideas was quite limited, as their epistemic view scores (i.e., 0.62 for World 2 views and 0.73 for World 3 views; all three aspects combined) were way below the average (which is 1.5, with the maximum score being 3.0). Moreover, Table 3 also shows that there were no significant differences between students' World 2 and World 3 views in any of the three aspects. In the post-test, it was found that there was a change in students' World 3 views, as their epistemic view score for the World 3 view increased from 0.73 to 1.67 (with all three aspects combined), while their World 2 views of ideas remained very much the same. This suggests that, after working collaboratively with ideas for a semester, students became more aware of the important role of ideas as epistemic entities for sustained knowledge creation. In particular, there were significant increases in the scores for each of the three coding aspects of the World 3 epistemic view. The participants tended to see that: (1) ideas can be treated not merely as abstract concepts, but as concrete objects that can be tinkered with and modified; (2) ideas can be derived not just from reflective thinking within one's mind-as-a-container, but from interaction with the physical world (e.g., by interacting with the environment); and (3) not only can ideas be used for personal knowledge growth, but they can be collaboratively and innovatively improved to advance community knowledge. Overall, the findings suggest that students started to develop a more informed World 3 epistemic sense that is critical for collaborative knowledge building.

Table 2. Comparisons between World 2 and World 3 epistemic views in pre-post tests

Test	Aspects of epistemic view	World 2 view		World 3 view		t-value
		M	SD	M	SD	
pre-test	Concrete object	0.34	0.48	0.32	0.57	0.22
	Interaction with the world	0.93	0.82	1.17	0.92	-1.08
	Advancing group knowledge	0.59	0.67	0.71	0.93	-0.61
	Three aspects combined	0.62	0.30	0.73	0.47	-1.24
post-test	Abstract concepts	0.32	0.47	1.44	1.00	-6.40***
	Reflection	0.61	0.67	1.66	1.28	-4.38***
	Personal knowledge growth	0.44	0.55	1.90	1.05	-5.70***
	Three aspects combined	0.46	0.31	1.67	0.81	-8.71***

***$p<.001$

Overall online interaction and inquiry activities

As mentioned earlier, in order to design technology products, students engaged in cycles of sustained idea improvement that required problem identification, idea generation, idea diversification, idea reflection, and idea synthesis. They usually began this process by identifying authentic problems derived from their personal life experience (M=13.90, SD=9.17 for the mean number of problems identified). They then moved on to produce initial ideas of how to address their problems of interest by posting notes online (M=27.49, SD=18.80 for the mean number of notes contributed). To diversify their ideas, they read and/or built on one another's notes (M=397.85, SD=225.67 for the mean number of notes read; and M=20.83, SD=18.75 for the mean number of built-on notes). In the meantime, to facilitate idea search and exchange for diversification, they marked keywords within notes (M=18.22, SD=15.06 for the mean number of notes that contained keywords). To reflect on and improve the ideas further, they tried to build on, annotate and/or revise one another's notes (M=8.15, SD=9.65 for the mean number of annotations; M=4.22, SD=4.02 for the mean number of revisions). They also used customizable scaffolds to facilitate the inquiry process (M=22.41, SD=21.09 for the mean number of scaffold

supports), with the purpose of integrating ideas for the eventual improvement of their technology products. All the online activity measures were found to be significantly correlated with one another ($.60 < r < .99$, $p < .01$), suggesting that the more actively the participants were engaged in one online inquiry activity, the more likely they were to engage in another activity as well.

Moreover, the learning groups in this course were formed based on individual interest in self-identified technology problems. To examine differences in group performance, the average score (M=6.90, SD=3.87) of students' epistemic views obtained in the pre-post survey was used as a separation point to divide the groups into more-informed groups (with higher scores) and less-informed groups (with lower scores). As a result, it was found that there was a significant difference in terms of epistemic scores between the more-informed groups and the less-informed groups ($F(1, 39) = 6.19$, $p < .05$). Further analysis of online performance was conducted, and it was found that the more-informed groups were more active, and engaged more, than the less-informed groups in all aspects of online activities except for the reading activity. However, none of the differences were statistically significant. But, when the length of inquiry for each group was counted and then compared, it was found that there was a significant difference between the more-informed and the less-informed groups ($F(1, 39) = 4.17$, $p < .05$), indicating that a longer inquiry time seemed to contribute to higher epistemic view scores.

Discussion

To sum up, knowledge-building pedagogy, with a focus on sustained idea improvement, seemed to be useful as a means to help students develop an informed World 3 epistemic view for knowledge advancement. However, if students only focus on lower-level idea exchange and sharing activities for knowledge building, their epistemic views may not change much. One important thing to note is that there was still room for students in even more well-informed groups to enhance their high-level inquiry skills in order to become more effective knowledge builders. Further studies will look into this to help us to identify more effective instructional know-how.

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Crossing Boundaries: Reflexive Analysis of Collaborative Learning in Research Institutions

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Abstract: Researchers have increasingly looked at characteristics of learning organizations, which engage in constant transformation to facilitate organizational learning in order to remain successful. While much of this research has looked at organizational practices and the embedded social networks within and across private firms, little research has reflexively considered academia. Yet, professional interactions within academic disciplines that cross narrow research specializations are critical for the continued advancement of public science. In this study, we employ a sequential mixed-methods study design to establish a base of empirical research that is introspective of the collaborative research environment of academia. We first employed purposeful semi-structured interviews to understand the value academic leaders place in cross-specialization interactions and then collected questionnaires from which we conducted statistical and social network analyses to describe the characteristics of and variation within disciplinary interaction networks and the relationships between network attributes and perceptions of a positive, collaborative learning environment.

Introduction

In our research, we seek to better understand the organizational factors that facilitate a collaborative learning environment for faculty researchers. This study therefore focuses on "research interactions," which we define as intellectual exchange across sub-disciplinary specializations within an academic discipline in ways that support the sharing of heterodox scholarship. As an example of this distinction, we seek more to capture professional interactions between a cognitive psychologist developing a learning tutor and a social psychologist researching attachment rather than those between two linguists who frequently collaborate together. We argue, as do many others (e.g., Maxwell, 2004; NRC, 2002; Phillips, 1993), that these diverse interactions are critical to the continued advancement of public research and the sciences.

Prior research investigating faculty communities in higher education finds significant cultural divides between disciplines and the sub-disciplines within them (Becher & Trowler, 2001) and characterizes the research environment as occupationally turbulent and extremely competitive (Cameron & Tschirhart, 1992). Current research into scholarly exchange often focuses on co-authorship and citation networks (e.g., Ding, 2011; Velden, Haque, & Lagoze, 2010) or on building research collaboration across disciplines and within the specializations that span them (Denicolo, 2004; Jedele, 2010). Previous research has also focused on organizational learning through network interactions within private workplaces (e.g., Cross & Israelit, 2009) and between firms (e.g., Larsson, Bengtsson, Henriksson, & Sparks, 1998; Powell, 1996) and how this leads to increased productivity. However, we found no empirical research that attempted to investigate the characteristics that support collaborative learning that spans research specializations within disciplinary communities in academia.

To address this gap, we designed a mixed-methods, dual-stage project to develop a foundation of the collaborative interactions among research faculty that do not share primary research interests. The first, qualitative phase focused on conceptualizing "interaction" using in-depth, semi-structured interviews with academic leaders. In the second, quantitative phase, we administered a questionnaire to research faculty and employed inferential statistics and social network analysis (SNA) to understand the relationships in each disciplinary unit of our research site.

Methods

In phase one, we generated a semi-structured interview protocol from a review of the literature. We included questions to elucidate research interaction in formal and informal contexts as well as how these interactions support a community of practice (Wenger, 1998). Items sought to bring to light the value researchers place on scholarly interactions across specializations, the function and dimensions of professional trust in academia, and how contextual factors such as the physical environment, available resources, and social hierarchy affect opportunities for interaction.

Interviews were conducted in tandem, with one researcher as the lead and the other taking field notes to supplement the audio recording. This phase employed responsive interviewing (Rubin & Rubin, 2012) to collect

data and a grounded theory approach (Strauss & Corbin, 1997) to move toward an understanding of interaction. Grounded theory allows us to consider both consensus and diversity of data to develop a rich but bounded working definition of academic interaction that allow for variation in perspectives.

For phase two, we operationalized the dimensions identified in phase one into a two-part questionnaire administered electronically to all tenure-track faculty in disciplinary units with doctoral programs at the university. We define the "disciplinary unit" as the highest organizational level that represents a conceptual discipline, such as "Psychology" or "Social Work"; thus, the disciplinary unit at times refers to different formal units within the same university. The first part of the questionnaire asks each participant to identify colleagues in the disciplinary unit with whom they interact, the frequency of interaction, and a set of context variables. We use these data for a social network analysis that examines the frequency, density, and structure of each research discipline in our site to understand the degree of variation in professional disciplinary communities. The second part of the survey captures salient indicators of the organizational environment, including beliefs regarding the collaborative climate, the degree that interactions across specialization lead to productive outcomes for the field, whether interaction patterns are influenced by race and gender, and whether the local collaborative environment is supported or impeded by factors that include technology, the layout of the physical environment, and social hierarchy.

Research questions for the full study include:

1. How do faculty leaders understand research interactions across specialization and to what extent are they valued for collaborative learning and scientific progress?

2. What factors impede and facilitate such interactions?

3. With what frequency do research interactions across specializations happen in disciplinary units and how much variation is observed across a broad set of them?

4. How do characteristics of interaction networks relate to perceptions of professional climate?

Sample

This study focused on all disciplinary units engaged in significant research at a large public university listed by the Carnegie Classification as having "high research activity." We used the presence of a doctoral program leading to a research Ph.D. as an indicator of a significant research focus; this led to the inclusion of 62 units. From this set, we constructed a typology of "fields", which are sets of disciplines with similar approaches (such as "the humanities").

For phase one, we categorized university and academic leaders based on the level of their responsibility and then selected interview participants in order to obtain perspectives on scholarly interaction that cross disparate fields, as different disciplines have significantly different cultures (Becher & Trowler, 2001). We also selected participants to maximize demographic variation as research shows that race and gender have salient effects on academic research contexts and networks (Sax et al, 2002; Scheurich & Young, 1997). A total of 16 academic leaders were included (see Table 1). While we succeeded in obtaining significant gender variation (N=7 female), the lack of people of color in academic leadership roles (as described by Aguirre & Martinez, 2007) made it difficult to diversify based on race (N=3 nonwhite). Interviews lasted 30 to 90 minutes and were in person, with the exception of one that was conducted by videoconference. Table 1 shows participant codes, administrative level, and field for the phase one interviews. We interviewed two leaders at the disciplinary level of the humanities as the units at our site do no formally define programs in a way that meets our criteria.

Table 1: Matrix of disciplines

Field:	Physical Sciences	Social Sciences	Interdisciplinary	Humanities	Professional
Example: **Level**:	*Physics,* *Biology*	*Education,* *Economics*	*Gender Studies,* *Ethnic Studies*	*English,* *Philosophy*	*Social Work,* *Engineering*
Above Discipline	♂	♀	♂	♂	♂
Disciplinary Unit	♂	♀	♀	♀, ♂	♂
Program	♂	♂	♀	*N/A*	♀, ♀

For phase two, a custom online survey that leveraged modern web interfaces and a database backend was designed and administered to all tenure-track faculty within identified units. The first part of the survey asked

the participant to select all faculty with whom they regularly interact and asked them to indicate (a) if they share the same research focus, (b) if they have collaborated in the last two years, (c) how often they interact in person and electronically, (d) whether they would approach that individual to ask a question in their field of expertise, and (e) whether they would approach that individual to ask a question about their professional life. From the salient constructs that emerged from the first phase, we generated and field tested 50 survey items; each construct had between three and seven items connected to it. We attended faculty meetings in disciplinary units to introduce the project and to increase response rates. We additionally contacted faculty non-responders directly by email. Only units with better than 50% response rates will be included in final analysis, and we will highlight the range of variation we see in network density, centrality, and perceived organizational environment in our selection of units for presentation.

Analysis

Phase one qualitative analysis

During interviewing, we performed preliminary analysis and open coded emergent topics to develop the initial code set. We iteratively refined the protocol and code book to increase clarity and gain further insight into emergent themes. After all interviews were completed and initially coded, we decided upon the final codebook using a consensus model and re-coded all interviews to ensure complete coverage.

Phase two quantitative analysis

The social networks for each disciplinary unit will be constructed and correlational statistics will be used to contextualize them. We compare network structures overall and consider centrality characteristics for individual nodes and for researcher cliques. Aggregated to the disciplinary level, we calculate measures for network centralization, network density, average tie strength, and clique census. From the survey questions, we calculate aggregate measures for perceptions of open sharing of research, fairness of resource allocation, factors in the physical environment, the use of new technology, and perceptions of cultural divides based on sub-discipline. We then use regression analysis to determine how organizational factors are seen to facilitate or inhibit the perceived collaborative environment and how it relates to network characteristics. We also will conduct HLM with disciplines nested within fields to see if there are systematic differences at the field level. Finally, we will conduct a cluster analysis on the results of the SNA and climate survey to determine where each disciplinary unit falls on three dimensions – network centralization, network density, and an aggregate indicator of the organizational climate.

Findings

Preliminary results from phase one participants indicate that there appear to be points of convergence across disciplinary units and points of divergence between both units and fields. The importance of informal interactions was consistently regarded as critical to both heterodox interaction and organizational learning in academia, which is consistent with similar findings in the private sector (e.g., Fayard & Weeks, 2007). The time requirements for interactions that would not directly benefit scholarly output were consistently regarded as a constraint. Most factors, however, were more nuanced and could either inhibit or facilitate scholarly interactions. This included affordances in the physical environment (e.g., office configurations or the availability of comfortable spaces that encouraged informal meetings), leadership practices and staff support, resource allocations, cultural divides between sub-disciplines, and differential treatment and expectations of women and researchers of color. Technology was notable as it is substantially changing the organizational context in ways that most academic leaders believe are not yet clear: new communication modalities were often cited as a benefit to formal interaction, but the lack of physical presence due to off-site work was a significant inhibitor to informal interactions.

Conclusions and implications

We find that all the academic leaders interviewed agreed that organizational practices and environmental affordances affect faculty interdynamics. Our study further establishes an empirical base quantifying the variation of characteristics. These include the collaborative environment and interaction networks within disciplinary communities of practice in academia. A limitation of our study is that the singularity of each discipline in our site prevents us from drawing inferences about broader cultures within disciplines or specializations. Future research will investigate whether variations are generally consistent, as well as provide insights into how interaction networks across schools might impact the role of local disciplinary units as learning organizations. More data is also needed to understand leadership policies that can improve the collaborative environment and

how knowledge transfer in research-based universities compares to private workplaces, where an established research base on organizational learning already exists.

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Using Differentiated Feedback Messages to Promote Student Learning in an Introductory Statistics Course

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Abstract: In light of the regulatory focus (RF) theory, an intervention was designed to promote student learning through differentiated feedback and then implemented in an undergraduate statistics course. Sixty-seven students were randomly assigned to receive the feedback that either fit or did not fit their RF. Results revealed a significant interaction between an individual's RF and the type of feedback received after controlling for the student's prior achievement. In particular, the students demonstrated better performance when receiving the fit feedback than the non-fit feedback. Further analysis of different performing groups showed that this identified interaction was significant only for the middle performing students, but not for the lower or higher performing groups. The findings suggested that the student's RF may moderate the impact of feedback on students' statistics performance, and this moderation pans out differently depending on the student's previous achievement.

Introduction

Feedback is often considered as an essential component in learning and teaching. Extant literature indicates that to become effective, feedback must be adaptive (Nicol, 2010) and be addressed in the context in which learning occurs (Hattie & Timperly, 2007); otherwise, feedback would produce inconsistent effects on learning outcomes due to the variations in student characteristics (e.g., Malachowski, Martin, & Vallade, 2013).

Unfortunately, many undergraduate classes afford limited opportunities for the instructors to provide adaptive feedback for each student (Voelke, 2013). The content of the feedback is often neither sufficient (Jacobs & Chase, 1992) nor adaptive (Nicol, 2010) to have desirable effects on learners. Moreover, very little effort has been made to examine the effectiveness of feedback (Price, Handley, Millar, & O'Donovan, 2010).

This study attempts to address these challenges by implementing a differentiated feedback strategy in an introductory statistics class in light of the regulatory focus (RF) theory (Higgins, 1997). In particular, we designed differentiated feedback to become aligned with the student's achievement levels and framed the feedback so that it would either fit or not fit the learners' RF. The major goal of this study is to determine to what extent the fit between the individual's RF and the type of feedback would affect students' course performance. We were also interested in whether such effect would differ for students with different previous achievement in statistics.

Regulatory focus

According to regulatory focus (RF) theory (Higgins, 1997), there are two distinct systems of self-regulation—i.e., *promotion* and *prevention*—which regulate goal-directed behaviors. The *promotion* system is mainly concerned with aspirations, accomplishments and advancement. Individuals with a promotion focus are inclined to focus on "the pleasurable presence of positive outcomes (Higgins et al., 2001, p. 4)", and therefore, use promotion strategies, such as risk taking and eager advancement, to achieve ideal goals. In contrast, the *prevention* system is primarily concerned with duties, obligations, and responsibilities. Individuals with a prevention focus tend to be prudent and precautionary to avoid negative outcomes (Crowe & Higgins, 1997).

Regulatory focus influences the motivational effects of feedback via regulatory fit (Higgins, 2000). When there is compatibility between an individual's goals and the types of feedback provided, regulatory fit occurs, and that leads to an increase in motivation and performance (Higgons, 1997). Past studies have examined regulatory fit in various fields (e.g., Florack & Scarbis, 2006) and in higher education (e.g., Shu & Lam, 2011). These studies indicate that a message can motivate people more effectively in fit conditions compared to non-fit conditions.

Methods

Participants and context

The study was conducted in a three-credit undergraduate course, Elementary Statistics, offered to the whole campus by the Department of Mathematics and Statistics at a state university in a Midwestern state in the US. Due to its large enrollment, the class was divided into 13 sections, with approximately 30 students each. Six

instructors were assigned to teach this course, with each teaching up to three sections. Since this study was a pilot project instead of a full-scale implementation, students from three sections ($n = 90$) taught by the same instructor participated in this study.

Design and procedures

In the first week of the semester, we invited the 90 students to complete a Regulatory Focus Questionnaire (RFQ; Higgins et al, 2001) and received 67 complete responses with a completion rate of 74.4%. Based on the responses, 46 students were identified as having a promotion focus, the other 21 students a prevention focus.

We randomly assigned the students with a promotion focus to receive either promotion or prevention feedback and repeated the same procedure to the students with a prevention focus (see Table 1). Taken together, 35 students received the "fit" feedback and 32 students received the "non-fit" feedback in this study.

Table 1: Students receiving promotion or prevention feedback through random assignment.

	Students with Promotion Focus	Students with Prevention Focus	Total
Receiving Promotion Feedback	24 (fit)	10 (non-fit)	34
Receiving Prevention Feedback	22 (non-fit)	11 (fit)	33
Total	46	21	67

Over the study, five quizzes were administered approximately every three weeks to evaluate student performance. The students took their first and second quizzes in the third and sixth weeks of the semester. The average scores on these quizzes were considered as the baseline data for student achievement prior to the intervention. After the second quiz, the students started to receive performance feedback about one week after each quiz. They would also receive a quiz reminder about a week before each quiz. Both the performance feedback and the reminder were differentiated to match either the promotion focus or the prevention focus. Moreover, the performance feedback was differentiated to align with the students' quiz performance levels.

Measures

Regulatory focus
To assess the students' RF, we used the Regulatory Focus Questionnaire (RFQ), which was composed of eleven Likert items asking the respondents' preference for promotion or prevention tasks (see Higgins et al, 2001).

Prior achievement
Students' prior achievement was determined by the average scores of Quiz 1 and Quiz 2.

Statistics performance
Statistics performance, evaluated based on the average scores of Quiz 4 and Quiz 5, was treated as the dependent variable in this study. Quiz 3 was excluded from statistics performance because its format was different from other quizzes.

Findings

Baseline performance
An independent-sample t test suggested no significant difference in prior achievement between students assigned to the fit condition and those in the non-fit condition ($M_{fit} = 69.94$, $M_{non-fit} = 68.41$, $t(65) = .37$, $p = .72$).

Overall effect of differentiated feedback on statistics performance
An analysis of covariance (ANCOVA) was conducted to determine the effects of the feedback on students' achievement. The dependent variable was the students' statistics performance. The independent variables were the students' RF and the type of feedback. The covariate was their prior achievement. The Levene's test was non-significant ($p = .10$), suggesting the assumption of homogeneity of variances was not violated. The results showed a significant interaction between the individual's RF and the feedback type ($F(1, 62) = 5.09$, $p < .05$, $\eta_p^2 = .08$), suggesting that matching the feedback to the individual's RF might significantly affect student learning (see Table 2). Subsequent analysis revealed that the fit group had higher statistics performance ($M = 61.80$, $SD = 23.81$) than the non-fit group ($M = 53.98$, $SD = 34.35$), although the difference was not significant ($t(54.60) = 1.07$, $p = .29$).

Analysis of students from different achievement groups

Students were divided into higher ($n = 23$), middle ($n = 23$), and lower ($n = 21$) performing groups based on their prior achievement in statistics. An ANCOVA was conducted within each group. The results of the Levene's tests were non-significant for all the three groups (all p's > .10). Results are presented in Table 2.

Table 2: ANCOVA results for the whole sample and the subgroups.

	n		df	F	p	η_p^2
Whole sample	67	RF	1	8.691	.005**	.123
		Feedback	1	10.166	.002**	.141
		RF * Feedback	1	5.091	.028*	.076
Higher performing	23	RF	1	.050	.825	.017
		Feedback	1	1.156	.297	.003
		RF * Feedback	1	.305	.587	.017
Middle performing	23	RF	1	3.592	.074	.166
		Feedback	1	9.798	.006**	.352
		RF * Feedback	1	7.870	.012*	.304
Lower performing	21	RF	1	4.802	.044*	.231
		Feedback	1	2.004	.176	.111
		RF * Feedback	1	2.055	.171	.114

Note: *p < .05. **p < .01.

For the higher performing group, neither the feedback nor the students' RF was found to have a significant impact on the students' statistics performances. The interaction between the two variables was not significant, either (all p's > .10). As Figure 1 shows, the students from the fit group had slightly lower scores than those in the non-fit group on every quiz of the semester, which seemed to be inconsistent with what the RF theory predicts.
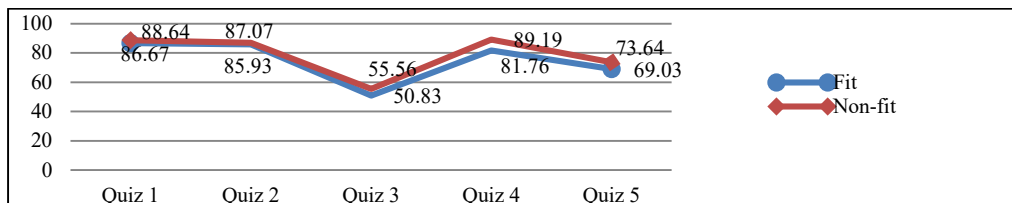
Figure 1. Average Score Comparison for Higher Performing Group.

For the lower performing group, the individual's RF was found to be significantly associated with the student's statistics performance. But neither the feedback nor its interaction with the RF was significant (all p's > .05). The students from the fit group had lower performance on Quiz 1 than the non-fit group, but they consistently achieved higher scores on the subsequent quizzes than their counterparts from the non-fit group (See Figure 2). Notably, the achievement gap between the fit and non-fit groups was larger on Quiz 4 and Quiz 5 than the first three quizzes. So, there might be subtle effects of the differentiated feedback ($F(1, 16) = 2.055$, $p = .171$, $\eta_p^2 = .114$) that are worth investigating in the future.
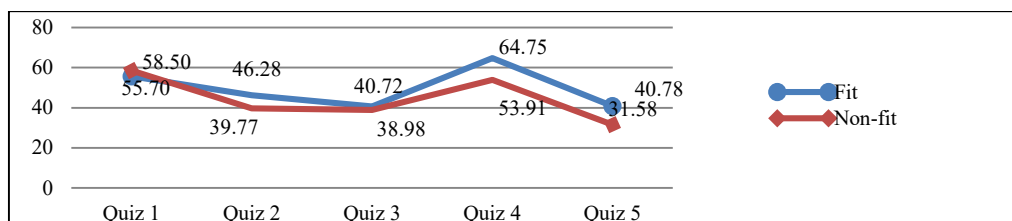
Figure 2. Average Score Comparison for Lower Performing Group.

Interestingly for the middle performing group, the student's RF was not significantly related to their statistics performance, but the feedback seemed to have a significant impact (F (1, 18) = 9.798, p = .006, η_p^2 = .352). Moreover, the interaction between the feedback and the individual's RF was significant (F (1, 18) = 7.870, p = .012, η_p^2 = .304). On the first three quizzes, the students from the fit group had comparable average scores with the non-fit group, but they outperformed their counterparts on Quiz 4 and Quiz 5, as shown in Figure 3. Further analysis indicated that the students who received the fit feedback had higher performances than those who received the non-fit feedback, although the difference was not significant (p > .05).
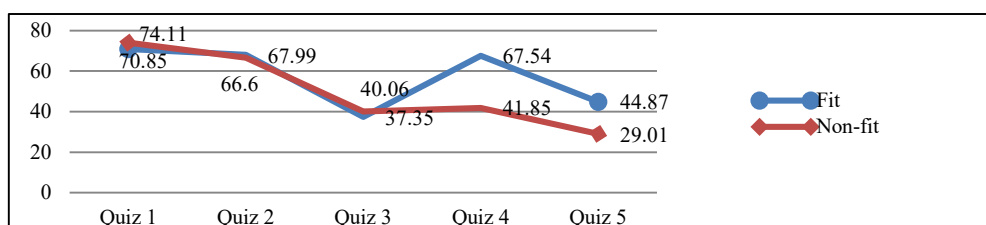
Figure 3. Average Score Comparison for Middle Performing Group.

Conclusions and implications

This pilot study applied the RF theory in an undergraduate course setting and generated empirical evidence about the extent to which the individual's RF could moderate the impact of feedback on student achievement. Results suggested that the alignment between the students' RF and the type of feedback could significantly affect learners' achievement. The findings further suggested that the learners' prior achievement could play a role in their responses to the feedback. In the middle- and lower-performing groups, the students receiving the fit feedback demonstrated better course performance than those receiving the non-fit feedback, but the pattern was not observed with the higher-performing group. When designing feedback, it is important to consider both the learners' RF and their prior achievement in order to improve their performance. It also seems necessary to explore better strategies to motivate the higher-performing students.

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Use of Interactive Computer Models to Promote Integration of Science Concepts Through the Engineering Design Process

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Abstract: During a *Solar Ovens* project in which middle school students design, build, and test solar ovens, students should also engage with science content to strengthen their designs. We integrate these two areas by using an interactive computer model to show how design decisions impact energy transformation inside a solar oven. This study investigates how students use a computer model to connect design decisions and science concepts at different points during a design project. Students engaged in either *planning* or *reflecting* by using the model before building or after, respectively. Students in the *planning* condition used the model in an exploratory manner, while students in the *reflecting* condition used the model to confirm the results of their physical solar ovens. Results suggest that using the model is helpful during both phases, but using the model during the *planning* phase helped students to better integrate their ideas about energy.

Keywords: science, engineering, computer models, technology, knowledge integration

Introduction

This research investigates how an interactive computer model could help students understand the interplay between science principles and engineering design decisions while carrying out a hands-on design project in a classroom setting. Often when students build a physical model they neglect the scientific basis for their decisions (Crismond, 2001). We address this challenge by engaging students in using a computer model that connects the science principles to their design decisions, consistent with the Next Generation Science Standards (NGSS) emphasis on science and engineering practices (NGSS Lead States, 2013). Interactive computer models can help students connect science principles and design decisions by making mechanisms such as energy transformation visible (Snir, Smith, & Grosslight, 1993; Wilensky & Reisman, 2006). Our research explores the effectiveness of the computer models, including whether they introduce confusions rather than supporting links between design decisions and energy concepts.

We used the knowledge integration framework to create a unit about solar ovens, with the goal of connecting design decisions and scientific principles (Linn & Eylon, 2011). The knowledge integration framework has proven useful for design of instruction featuring dynamic visualizations (Ryoo & Linn, 2012) and virtual design activities (Chiu & Linn, 2011; McElhaney & Linn, 2011). The framework supports linking of ideas by first eliciting all the ideas students think are important, then engaging them in exploring their ideas. When students build a physical artifact they can often only test a few of their ideas due to time and material constraints. Modeling allows students to explore many more ideas.

Besides testing the overall advantage of modeling for knowledge integration, we also investigate whether it is more effective to use modeling to connect design decisions and principles prior to building a physical model or following the model construction and testing. Modeling before building the physical oven could help students distinguish among alternatives such as whether to line the inside of the solar oven with black paper or with foil. Modeling after building a physical model could enable students to test conjectures that arose during the construction of the oven. The computer model we designed illustrates the flow and transformation of energy in a solar oven and allows students to make design choices and compare multiple designs

Methods

Participants and procedures

Two teachers from one middle school serving a diverse population (42% reduced lunch, 13% ELL) participated in this study. A total of 252 sixth grade students participated in this study, completing a pretest, the curriculum unit, and a posttest. The pretest was conducted one day before beginning the unit, and the posttest one day after

finishing the unit. Both the pretest and posttest were administered to students individually. Pairs of students were assigned to collaborative workgroups by their teacher to work on curriculum. Workgroups were randomly assigned to a condition (*planning* or *reflecting*) by the software and received the same activities in different orders.

Curricular materials

This study was implemented in a curriculum module entitled *Solar Ovens and Solar Radiation* (referred to as *Solar Ovens* in this paper). The goal of the unit was to familiarize students with the way energy transforms from solar radiation to heat through a hands-on project and interactive models, covering the modeling aspect of the Science and Engineering Practices of the NGSS, as well as the standards associated with energy, specifically standards related to the transfer of thermal energy (NGSS Lead States, 2013). Students engaged with the curriculum in WISE (Web-based Inquiry Science Environment), utilizing a variety of instructional and assessment tools (Linn & Eylon, 2011).

Table 1: *Solar Ovens* Curriculum. Students used the model EITHER for planning or for reflecting.

Activity	Description & Items of Interest
Introduction to Solar Ovens	Elicit initial student ideas about energy transformation
Solar Radiation and the atmosphere	Energy comes as radiation from the sun; energy can be absorbed or reflected. Students use a simulation to investigate energy.
Solar Radiation and Greenhouse Gases (GHGs)	Describes how energy interacts with greenhouse gases. Students use a model to investigate how addition of GHGs impacts energy.
Model for planning condition	**Students use an interactive model to investigate how radiation works in a solar oven [*Trials* item]**
Design, Build, Test 1	Design oven under budgetary constraints using a draw tool, build, test under a heat lamp using a temperature probe to collect data
Design, Build, Test 2	Students reflect on what was learned from the first iteration; use new budget constraints to repeat process [*Learn* item]
Model for reflecting condition	**Students use an interactive model to investigate how radiation works in a solar oven [*Trials* item]**
Reflect	Students describe how their solar ovens work using energy from the sun; make connections between solar ovens and the atmosphere [*Atmosphere* item]

Table 1 displays the general layout and features of the *Solar Ovens* curriculum unit. In this study we highlight those steps after the conditions diverge, specifically the embedded *Trials, Learn,* and *Atmosphere* items. In the *Trials* item students were asked to run at least three trials on the solar oven model, then write about what settings they used, how hot the oven got, and how long it took for the oven to get that hot. In the *Learn* item, which occurred between the two Design, Build, Test (DBT) iterations, students were asked what they learned from their first trial and how they will improve their design during the second iteration based on what they learned. In the *Atmosphere* item, students were asked to compare and contrast how radiation works in the atmosphere and in a solar oven.

The solar oven model was designed using NetLogo (Wilensky, 1999) (Figure 1). Each time students viewed a model, they made a prediction, interacted with the model to test their prediction, and wrote about whether their prediction was correct or incorrect and why.
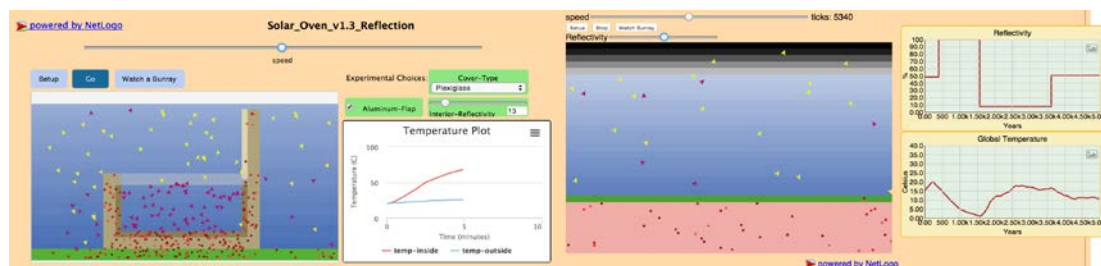
Figure 1: Screenshot of solar oven model (left) and solar radiation and the atmosphere model (right)

Test materials

The pre- and posttest assessments measured student ability to link concepts about energy. Typically the items offered a choice among options and asked for a written explanation of the choice, consistent with the knowledge

integration emphasis on linking ideas. For example the, *Car on a Cold Day (Car)* asked students to explain what would happen to a car left in the sun during a cold day. In another item, *Laura's Car,* students were asked what color interior and exterior Laura should have on her car in order to keep it the coolest on a sunny day (*Laura1*), and to explain whether or not Laura should use a sun shield to keep her car cool (*Laura2)*. Students were also shown two pictures, of greenhouse gases in the atmosphere and of a greenhouse, and asked to compare them in *Greenhouse Gases 1 (GHG1)*, then asked to compare the atmosphere and a greenhouse with a solar oven in *Greenhouse Gases 2 (GHG2)*. One item, *Model,* asked students to use a basic solar oven model to answer help a fictional student determine whether a tall, skinny box or a short, wide box would heat up faster. The pretest is made up of the *Car, Laura1, Laura2, GHG1,* and *GHG2* items, while the posttest is made up of these same items with the addition of the *Model* item.

Analysis approach

To measure knowledge integration, the items were scored using knowledge integration rubrics to assess links between multiple normative science ideas (Linn & Eylon, 2011; Liu et al, 2008). The knowledge integration rubric for *Cars* shows how links are scored (Table 2).

Table 2: KI scoring rubric for "Car on a Cold Day" pre/post open response item

Score	Level	Examples
0	**No Answer**	
1	**Off Task**	*I don't know.*
2	**Irrelevant/Incorrect**	*The inside air and the outside air are the exact same temperature because the sun is not enough to heat the inside if the car.*
3	**Partial** Normative isolated ideas without a valid link	*The solar radiation would go through the metal and would stay in the car when the outside air wouldn't be able to get inside.*
4	**Basic** Elaborate a scientifically valid link	*it would be warmer than the outside air because if the car hasn't been driven for a week and its been in the sun the whole time the car will absorbe the heat and scence there is know way the heat can get out of the car the heat will just keep building up.*
5	**Complex** Elaborate two or more scientifically valid links	*The sun produces solar radiation which heats up the car and the infrared radiation gets trapped in the car which leads to the temperature rising.*

The *Learn* and *Atmosphere* items were scored using knowledge integration rubrics, while *Trials* was evaluated using an adjusted knowledge integration rubric. *Trials* was evaluated for use of numerical evidence, mention of energy transformation mechanisms, and completion of *Trials*, with students earning one point for each piece included in their response for a possible total of three points.

Results

Students in the *planning* condition outperformed students in the *reflecting* condition on posttest [*planning:* M=15.54, SD=0.32; *reflecting:* M=14.83, SD=0.26]. A t-test of pooled pre- and posttest data across conditions (*Car, Laura1, Laura2, GHG1, GHG2* items*)* revealed a significant effect of testing session [$t(473) = -5.81$, $p < 0.001$], demonstrating that across both conditions students made gains from pre- to posttest. A regression model showed that posttest scores were significantly influenced by condition when controlling for pretest scores [$F(247) = 27.11$, $p=0.05$], suggesting a benefit from interacting with the model earlier during the unit.

These results suggest that interacting with the solar oven simulation before DBT might be most beneficial, if time constraints allow for only one modeling phase. Additional support for this claim comes from the *Model* posttest item. Students in the *planning* condition performed slightly better than students in the *reflecting* condition [$t(240) = 1.88$, $p < 0.06$]. This is surprising since students in the *reflecting* condition would have the added benefit of interacting with a similar computer model recently (during the end of the unit), while approximately one week had elapsed for students in the *planning* condition since they interacted with the embedded model.

Students in the *planning* condition also performed better on scored items embedded in the unit [*Learn:* $t(248) = 2.43$, $p < 0.02$; *Atmosphere:* $t(248) = 1.83$, $p < 0.06$; *Trials*: $t(248) = 4.10$, $p < 0.001$]. Higher scores on the *Learn* and *Atmosphere* items, which were scored using a knowledge integration rubric, indicate that students were able to add more normative ideas and connect their ideas together. Higher scores on the *Trials* item indicates students used the model to run trials of their existing or future ovens, wrote about the results using numerical

values, and connected the energy concepts with their design choices. A regression model also showed that posttest score across conditions was by influenced by score on the *trials* item, when controlling for pretest score [$F(247) = 30.57$, $p < 0.02$], indicating that students who scored higher on the *trials* item were more likely to score highly on the posttest.

Conclusions and implications

This study shows how students use computer models in conjunction with hands-on activities. This combination allows students to connect science concepts to their design decisions.

During the Solar Ovens unit, the modeling activity strengthened the links between the science concepts and design decisions, offering students a space to plan and test their designs in the *planning* condition, or to confirm their results and make further connections after they engaged in design process (*reflecting* condition).

Students who used the interactive model for *planning* during the unit were more likely to make gains on the integration of energy concepts between pre- and posttest. Many students in the *reflecting* condition used the model for very simple confirmatory analysis of models they had already built, which was not as helpful as using the model during the *planning* phased to connect science and design ideas.

In future studies we plan to explore patterns of student interactions with the model by collecting log data. The log data will consist of the clicks students make within the model and the time at which they make them. Using this data, we will also be able to evaluate the amount of time students spent on the model, how that differs by student pair, and how systematic or unsystematic students explorations with the model are. Some early research has been done on analysis of student log data from interactive computer models, showing that this is a feasible addition to our research on student use of computer models (Conati et al, 2015).

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Examining the Influence of Teacher's Framing of Modeling Practices on Elementary Students' Engagement in Modeling

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Abstract: Scientific modeling is one of the core scientific practices that are critical to learner's knowledge-building. Despite the increasing emphasis on scientific modeling in the community of science education, more information/research is needed to better inform teachers as to how they can support epistemically-rich, non-procedural engagement in modeling. In this study, we use *Epistemologies in Practice* as our theoretical framework to examine students' engagement in modeling practice. We used a comparison approach to analyze 26 classroom video recordings in order to understand how two teachers framed modeling practices in the same modeling-based unit. In doing so, we analyzed what support teachers provided students as they engaged in modeling and how that might have led to students' engagement in several epistemic aspects of modeling practices. Our findings suggest that how teachers framed the purpose and goals of modeling appeared to have a great influence on how students engaged in the modeling practice.

Introduction

Within the past two decades, reform efforts in science education (National Research Council, 1996) have increasingly called for engaging students in authentic scientific practices such as scientific modeling, argumentation, and scientific explanation that resemble the intellectual work of scientists. This "practice turn" with respect to K-12 reform efforts (Ford & Forman, 2006) recognizes the importance of engaging students in communities of practices (Wenger, 1998) where they become active participants in generating knowledge and figuring out how the natural world work the way they do. Therefore, it is critical for students to engage in scientific practices in a scientifically meaningful rather than a procedural way. Among scientific practices, scientific modeling has been considered particularly important since constructing, testing, and revising models lies at the heart of scientific endeavor (Lehrer & Schauble, 2006). In the recent release of the Next General Science Standards (NGSS; NGSS Lead States, 2013), scientific modeling is highlighted as one of the eight core scientific practices in which students should engage in order to make sense of the world. However, little is known about how teachers can support students' scientifically meaningful engagement in scientific practices in general, and scientific modeling in particular, as required by the NGSS.

In this study, we addressed this critical need by examining how teacher's overall framing of scientific modeling might influence students' engagement in the modeling practices. We focus on teachers' framing because teacher's values and goals of the practice, as well as the way they frame it can influence how the practice unfolds in classroom (Berland & Hammer, 2012). By comparing and contrasting two teachers' framing of modeling practices in the same modeling-based unit, we seek to understand what support teachers might provide with students while engaging in modeling and how it might, or might not lead to students' engagement in various aspects of modeling practices. In particular, we ask the following two research questions,

1. How do the teachers frame the purposes or goals of modeling practices over the course of a model-based unit?
2. How might teachers' framing of modeling practices influence students' engagement of scientific modeling?

In this paper, we use Epistemologies-in-Practice framework (in press) developed by our larger research group as our theoretical framework to examine students' engagement in modeling practice. We argue that in order to make students' engagement in modeling scientifically meaningful, students must be guided by the epistemic considerations that characterize some of the norms and values of science. By epistemic considerations, we refer to the purposes and goals of the work students are engaged in. For example, developing and revising models that address the mechanism of phenomena lies at the core of the scientific endeavor; therefore, considering the degree to which an explanation is mechanistic should guide learners who are engaged in modeling practice. We termed these epistemic considerations that frame and guide practices "epistemologies in practice" (EIP). The term Epistemologies *in practice* refers to both the practice-based perspective of student learning and the emphasis on students' epistemological ideas *in use*. This EIP framework is helpful for this study because not only can we capture the nature of students' engagement in modeling practices, we could also use this framework to see how teachers support students' development in epistemic considerations of modeling in classroom community.

The EIP framework focuses on four epistemic considerations (ECs), Nature, Generality, Justification, and Audience. The Nature EC refers to students' ideas about the nature of the model or the kind of answer the model should provide, which could range from describing *what* happens in details, to identifying key factors of the phenomena, to explaining *how and why* something happens. The Generality EC relates to how specific phenomena or experiences relate to one another and to more general scientific ideas. A student who is viewing his/her model as connecting a range of phenomena could apply the model to a specific phenomenon or explain how multiple phenomena are accounted for in the model. The Justification EC focuses on students' thought about why their ideas in the model are correct. A student could include the information that others told him/her to include without justification or he/she could use empirical evidence or theoretical information to justify his/her model. The Audience EC reflects how students identify and orient their model for a particular audience and their understanding of how that audience will use their model. A more detailed description of the four epistemic considerations will be included in the full paper.

Methods

Contexts and participants

To investigate our research questions, this paper reports on the analysis of two 5th grade classrooms taught by two teachers (Mrs. M and Mr. H) in a Midwest suburban elementary school during the 2012-2013 academic year who have worked with our research group for 7 years on how to engage upper elementary students in scientific modeling. As a result, we have a long history and extended involvement and interactions with both teachers. Both teachers taught a 6 to 8-week model-based unit about evaporation and condensation; for both, it was their 4th time teaching the unit. In the unit, students are asked to address a driving question whether or not they would drink the liquid from a solar still. To answer this driving question, students constructed an initial diagrammatic model to explain the phenomenon, and continuously evaluated and revised their models using evidence from their empirical investigations and scientific information. The evaluation and revision process involves discussions within small groups and whole class. In each teacher's classroom, we focused on one group of students (called "focus students") and video recorded them while they are constructing their consensus models. Each group consisted of four students selected by the teacher.

Data collection

The primary data for this paper include video-recordings of every lesson each teacher taught except those in which students were expected to do investigations or explore computer simulations of molecular movement. In those modeling lessons we video-recorded, students were expected to construct, revise and evaluate their models of evaporation and condensation. These lessons were critical for showing us how the teachers framed modeling at different stages of the curriculum as well as how students were engaged in the practice of modeling, both in whole-class and small group settings. Each recording was transcribed and analyzed. In total, we analyzed about 12 hours of classroom-recorded lessons from the unit for each teacher. Each 45-minute class period for the unit usually consisted of both whole class discussion led by the teacher and small group discussions among students.

Data analysis

In order to answer the first research question, we analyzed what the teacher said to students in each lesson. First, we summarized how the teacher talked about the purposes or goals of modeling in each lesson. The unit of analysis was an utterance, which we define as bound by a clear pause or silence. Next we used a modification of grounded analysis (Glaser & Strauss, 1967) to identify patterns across the summaries of teachers' goals. This was iteratively conducted for each teacher. By comparing and contrasting those summaries, we collapsed them into a more general theme that represents the teachers' overall framing of modeling practices over time.

In order to answer the second research question, we analyzed the small group discussions among focus students when they constructed consensus models of evaporation and condensation. Similar to the analysis of the teachers' talk, the unit of analysis was an utterance. Since we were interested in whether students are engaged in the modeling practices in a scientifically meaningful—rather than procedural—way, we used two codes to analyze group discussions: epistemic and task-oriented. While epistemic utterances convey students' ideas about the purposes or goals of modeling practices as our EIP framework suggests, task-oriented utterances focused on how to finish the tasks. Therefore, task-oriented utterances often involved questions or suggestions about what to include in the group model specifically without explicitly stating the rationale for doing so. We also used the four epistemic considerations to identify which epistemic considerations students' considered and how that might have been influenced by the teachers' framing.

Findings

Teachers' framing of modeling practices

Analysis of video-recorded data indicates that Mrs. M emphasized the notion that "use models to explain different phenomena" consistently throughout the unit. This framing of modeling highlights the utility of models and incorporates both the Generality and Nature epistemic considerations. The following excerpt exemplifies what Mrs. M's framing looked like in the classroom and can be seen in 33 other utterances throughout her instruction. At the beginning of that particular class period, Mrs. M explicitly stated the goal of what they would be doing as a class, "today is evaluating our consensus models and come up with ways that we can use our consensus model to apply to other phenomena." The conversation happened in the middle of that class period when students were presenting their group consensus model of evaporation in front of the class.

Mrs. M:	Your group used open cup-closed up as your phenomenon of your model. Selina, *I'd like you to use this model to explain what happens to the dew on the ground in the morning and why it's not there when you get out.* [Framing of modeling: Explain different phenomena]
Selina:	So like the water would be the dew. The water molecules in contact with air molecules and they evaporated.
Mrs. M:	What happens to those water molecules when they meet the air?
Selina:	When the air molecules hit the [water] molecules, it depends on the temperature at the time, it's gonna turn into water vapor and go out.

In this excerpt, Mrs. M asked Selina to use their consensus model to explain a new phenomenon, dew disappearing from the grass, which reflects Mrs. M's overall framing of modeling, "use models to explain different phenomena." In other words, Mrs. M focused on the explanatory nature of models and how it can be applied to different phenomena.

In comparison, Mr. H often highlighted the idea of "scientifically correct information should be put into models." This framing of modeling highlights the role of the model as an end product rather than an explanatory tool. For example, when his students were to revise their initial models of evaporation after some investigations of phenomena of evaporation, he said, "All this information we've been gathering, should be in our model somewhere." Throughout the unit, Mr. H had similar utterances about this 'model as container of correct information' notion of modeling and focused on the correctness of information that students put into their models. In addition, later in the unit, Mr. H started to worry about the amount of time his students spend constructing the consensus models within the small group. Therefore, one of the goals of the modeling practice became "finish in time." Mr. H explicitly told his students "the goal today is trying to finish this up", and also made "majority rule" the criteria to solve disagreement among group members instead of other scientific criteria such as how the model is supported by empirical evidence in order to speed up the consensus modeling process.

Teachers' influence on students' practices

Analysis of small group conversations when students' were constructing consensus models of evaporation and condensation, mirrors the framing teachers' shared with students above and indicates that students in Mrs. M's class tend to focus on the epistemic aspect of modeling practices. For example, during a 20-minute group discussion when Mrs. M's focus group were constructing their consensus model of evaporation, we recorded 16 utterances of Nature EC talk, 6 utterances of Generality EC talk, 8 utterances of Justification EC talk, 5 utterances of Audience EC talk and 9 utterances of task-oriented talk from the focus group. Below we present an excerpt from that discussion that is representative of how Mrs. M's focus group engaged in the practice of the constructing consensus model.

Sue:	We have to explain it didn't seep through the cup, if someone asked that. [Justification] Our model cannot explain that. [Nature]
Jack:	Well does this explain how paint dries? [Generality]
Sue:	Yes. The water molecules are leaving. This explains how nail polish dries. It also explains how you can smell stuff because molecules go away carrying scent. [Generality]

Emilia:	How about label? Did you label it? Like an open cup. [Task-oriented]
Ben:	We know it's an open cup. If you shaded it in, it's obviously a closed cup. I bet if you show it to somebody, they would know this is uncovered and this is covered. [Audience]
Emilia:	I'm just saying, it's good to label, just, just saying.

As the transcript indicates, at the beginning of the conversation, Sue thought about an alternative idea about why water disappeared over time (water seeping through the cup instead of going to the air) and she proposed to justify in the consensus model why water molecules going to the air is correct, which relates to the Justification epistemic consideration. Then Jack asked the question, "Well, does this explain how paint dries?" Jack's question was very important for answering our second research question because it reflected Mrs. M's framing of modeling, "using models to explain different phenomena." In the previous excerpt, Mrs. M asked one student to apply their model to explain why dew on the grass disappeared. Here, Jack was echoing Mrs. H's questions, asking his peer if their consensus model is general enough to explain other phenomena such as paint drying. Multiple instances of the group work indicate that Mrs. M's framing of modeling may influence the kind of question Jack posed to the rest of the group.

Compared to students in Mrs. M's class, students in Mr. H's class tended to be more task-oriented or procedural while engaging in modeling practices. The nature of the focus group conversation is task-oriented most of the time and occasionally they attended to Nature EC as they were trying to figure out the mechanism of evaporation or condensation. For example, compared to 21 utterances of task-oriented talk, we only observed 5 utterances of Nature EC talk when the focus students were constructing the consensus model of evaporation during a 20-minute discussion. Also, the group did not attend to any other epistemic considerations during that period of time. We hypothesized that the procedural nature of the conversation might result from how Mr. H framed the purpose and goals of modeling overall, seeing models an end product.

Conclusions and implications

The analysis indicates that Mrs. M and Mr. H framed scientific modeling differently – Mrs. M framed the modeling process as a tool to explain multiple phenomena, while Mr. H framed model as an end product filled with scientifically correct information. We can also see how the framings were echoed in their students' small group work respectively. As shown above, the small group work from Mrs. M's class focused on multiple epistemic considerations of modeling practices while Mr. H's mostly focused on procedural aspects of modeling practices such as labeling components.

The findings suggest that how teachers frame the purpose and goals of modeling might have a great influence on how students engage in the practice of modeling. Students will engage in a more scientifically meaningful way if the teacher supports them in thinking about the epistemic considerations. In addition, the findings indicate that it is important to consider modeling practices in school settings where other goals of instruction co-exist. In order to make the practice scientifically meaningful for students, teachers should balance those goals and provide a learning environment that prioritizes the epistemic considerations of modeling practice.

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Learning the Learning Sciences:
An Investigation of Newcomers' Sociocultural Ideas

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Abstract: The sociocultural perspective is one of the key ideas of the Learning Sciences. For the field to sustain and expand its collective knowledge and practices, it is vital to enculturate sociocultural thinking to new generations of scholars and practitioners. In this short paper, we advance this goal by investigating the way students who study the Learning Sciences come to view learning from a sociocultural perspective. Here, we focus upon one case study within the context of an affiliate of the Network of Academic Programs in the Learning Sciences. Our findings indicate three ideas that signify sociocultural thinking: (1) Collaboration-as-learning; (2) Culture as relevant to learning; and (3) Learning as a process.

Keywords: collaboration, enculturation, higher education, learning community, sociocultural

The teachers of the future will be knowledge workers… They will deeply understand the theoretical principles and the latest knowledge about how children learn. (Sawyer, 2014, p. 730)

Introduction

The aim of this research is to elucidate the way students come to view learning from a sociocultural perspective. This is the subject of intense interest for the Learning Sciences (LS) research community, which has been deeply influenced by sociocultural theories and seeks to sustain and expand its collective knowledge and practices to new generations of scholars and practitioners. While there have been many efforts to make LS content accessible to students, such as through textbooks like How People Learn (Bransford, Brown, & Cocking, 2000), an extensive collection of webinars that cover the foundations of the discipline (isls-naples.psy.lmu.du), and in dozens of international graduate programs, only few empirical studies relate to how students learn the ideas of the discipline itself (e.g., Rogoff, 1994). By focusing upon the sociocultural perspective, we may not cover the entire field, but do capture some of the most significant and complex ideas that newcomers must master to participate in LS discourse (Sawyer, 2014).

This research is motivated by our experiences as graduate students, instructors, and researchers within a unique learning community: The Educational Technologies Graduate Program (Edtech) at the University of Haifa, Israel. Founded in 2005, Edtech has gradually grown over the years to include approximately 20 Master's level students in each of the two annual cohorts, 20 doctoral and post-doctoral researchers, and five full-time faculty. While LS literature has always been at the center of studies, Edtech formally joined the Network of Academic Programs in the Learning Sciences (NAPLeS) in 2013. From the very start, Edtech was designed to enculturate its students into the LS. One prominent design feature that was derived from this approach was the idea that the process of learning must match the content. As students study ideas such as communities of learners (Brown & Campione, 1994), they participate in a learning community (Hod & Ben-Zvi, 2014, 2015).

We report upon a specific case of a master's level student as a step in more generally elucidating the way students come to view learning from a sociocultural perspective. In the following section, we provide an interpretation of the sociocultural perspective which provides the framework used to interpret our findings.

Background

Sociocultural theory is rooted in Vygotskian thought, and particularly in his idea that learning is mediated by cultural and historical tools that individuals internalize and appropriate as they are socialized throughout their lifespans. Human higher mental functioning occurs first on an intermental plane, and with the aid of mediators such as tools, signs, and language, it continues on an intramental plane (Wertsch, 2007). Such an "outside in" perspective contrasts sharply with cognitive views which emphasize learning processes which are initiated first inside a person's head, then socially, "inside out" (Collins & Bielaczyc, 1999).

Vygotskian ideas have germinated into many directions (e.g., activity theory, distributed cognition). Due to space considerations, we will limit ourselves to situated learning and the discursive approach. One major

contribution to situated learning is based on Lave and Wenger's (1991) ideas of Communities of Practice (CoP). This view of learning "implies becoming a different person [and] involves the construction of identity" (p. 53). Meaning, learning is a process whereby a newcomer in a CoP, who is initially a legitimate peripheral participant, gradually takes on more meaningful roles within the CoP and thus enculturates its practices.

Lave and Wenger's sociocultural framework has become the basis of many key ideas within the LS, particularly due to its commitment to education (Sawyer, 2014). By identifying enculturation as a key construct in the learning process, researchers have found useful ways to talk about the problems of instructionist pedagogies and to think in new ways about how to design for authentic learning. As Brown, Collins, and DuGuid (1989) pointed out, traditional education too often fails to give students experience in the relevant domain culture. For example, students learning mathematics in school may practice solving long lists of equations so they can perform successfully on a test, a practice that hardly resembles the way the community of practicing mathematicians engage in their discipline. The implication of this view for schools has been to re-conceptualize classrooms from places where knowledge is transmitted to learning communities (Bielaczyc, Kapur, & Collins, 2013). In taking a community perspective, an array of mediators beyond just transmitted content becomes the subject of educational design.

The discourse about learning and education in the years that followed these large insights was analysed by Sfard (1998), who very lucidly showed how this new "sociocultural way" of talking about learning stood in contrast to cognitive views. The key insight was that sociocultural views looked as learning as an action, while cognitive views reified these actions into objects. These two views are expressed in discourse as different metaphors of learning. Whereas metaphors that are sociocultural include participation, being a part of, and enculturating, cognitive metaphors objectify these actions into knowledge and concepts that can be acquired and possessed. This discursive perspective was not only useful in clarifying how these perspectives differed, it provided a clear operationalization for analyzing students' views on learning.

We see these different but interrelated views of sociocultural thought as tools to examine students' developing sociocultural ideas. Given the situativity of learning, we don't expect to find direct correlations of students' understandings with what we have presented here. Rather, we would like to examine the relationship between students' knowing about sociocultural ideas with their coming to be part of Edtech.

Methods

The findings presented here are part of a larger case study of Master's level students within Edtech. This specific paper follows one of these students. Our data sources included careful observations of face-to-face course meetings, online artifacts from students' work, and periodic interviews. Data were analyzed using micro-genetic techniques, looking at a fine-grained level of detail at meaningful episodes of learning where they were situated. As our interpretations emerged throughout careful examination of the data, these were triangulated only after multiple sources of data were found.

Preliminary findings

We focus upon Andrea, a central member in the National English Teachers' Community. Andrea entered Edtech as an experienced elementary school English teacher who engaged in numerous educational activities that eventually transformed into other professional roles. She received recognition for creating and maintaining a vast portal for online English learning resources. Moreover, Andrea was on national committees to develop English curriculum and led teacher training programs. She received a national teacher of the year award.

As an incoming student to Edtech, Andrea was immersed in numerous web communities such as Twitter, Google Plus, and the blogosphere. Andrea's offline behavior in Edtech was consistent with her online activities. She was very social and popular with other students. Even in her studies, she was among the most active and contributing student across all the courses that she participated in.

Andrea was in many ways a perfect fit for Edtech due to her technological prowess and central role in the teachers' community, where there was heavy focus on practice and technology. This often contradicted the norms of Edtech's culture of learning, such as deep inquiry, revision, and collaboration. The contrasts between these communities made Andrea an interesting case to study, which we report upon here.

Sociocultural idea 1: Collaboration-as-pedagogy to collaboration-as-learning

Although Andrea was a social person, her ideas about collaboration when she entered Edtech developed throughout her studies. At the start, Andrea focused upon collaboration as a structured activity:

The instructors around me can put in front of me all the good opportunities for learning, but the process itself I do by myself, alone. The community can sit together, the group can work together and in great collaboration and also with the product of a certain project that was built together, still the learning is personal, individualistic…

By the end of the program, she shifts from talking about the pedagogical aspects of collaboration to considering its part within the learning process:

Every word and every little bit... had to go through this thin sieve and those unforgiving eyes up to the process in which I learned to know that nothing can be taken for granted and ahead of time I started thinking of all the directions I expected Nora to come with. Slowly we started to work collaboratively with mutual respect and the knowledge that the two of us together are much better than each of one on her own.

Sociocultural idea 2: Culture as relevant to learning

Halfway through the first semester of studies, Andrea took part in a collaborative activity where students were asked to read *Situated Cognition and the Culture of Learning* (Brown et al., 1989) and create concept maps to represent their shared understandings of it. Andrea played a leading role in her group. The final version included separate collections of key terms from the article. However, there was no evidence that culture was in any way meaningfully related to learning, rather, it was presented as an isolated idea.

In reflecting about an incident towards the end of the first year, Andrea pinpointed the first time where she saw the relevance of the idea of culture in relation to learning:

We knew where we are going and we knew what we want, but we didn't know how to call it till Cindy casually noted, "you want a change in the instructional culture." And from there it was clear what is the name of the place that we want to reach.

Sociocultural idea 3: Learning as a process instead of product

Andrea's background attests to the product-orientation that she had as a learner upon entering the program. Within the first few weeks, the culture clash between her ways of working and the norms in Edtech created tension that she described. In her work culture, her practice was to complete tasks as efficiently as possible. But under a similar load in Edtech, she had to think about how to proceed so that she could learn in the best way possible. Her cultural habits of getting things done created tension for her:

There are critical assignments that must be implemented immediately. There is the concept map, initiatives, diary… So please someone explain how I can live with all this? Is it possible? Even if I slow down reality doesn't change.

By the end of the program, a noticeable shift in Andrea's expectation of herself when faced with a heavy load was evident. In the context of an ongoing collaboration that she had with another student, she showed deep appreciation of the role that the collaborative process has in learning, instead of racing to achieve a product:

The process throughout the project... taught me what is design research and what is the place of the whole process… If I wouldn't have gone through all the mistakes we made and experienced all the difficulties on the way, I wouldn't have reached all these insights… Today I am at the start of the road.

Discussion and conclusions

As sociocultural thinking involves some of the most significant ideas of enculturating LS discourse, this ongoing study attempts to elucidate the way students come to view learning from this perspective. In the case presented here, we show some of Andrea's preoccupations when she studied within a context that was designed based on

sociocultural ideas, and where students study sociocultural content. We have found three ideas that are relevant to the development of sociocultural views.

As we show in the background section, sociocultural thinking involves both ideas about learning and pedagogical ideas that stem from them. However, teachers entering programs such as Edtech often focus upon pedagogical ideas before they develop their understanding of the principles that underlie them. Andrea exemplifies the vital transformation in the first idea, *collaboration-as-pedagogy to collaboration-as-learning*, from focusing upon her situated experiences from a pedagogical lens into a learning lens.

The idea and relevance of culture is fundamental to understanding sociocultural thinking. Without seeing the relevance of culture to learning, Vygotsky's entire idea of the interpersonal plane is lost. Likewise, participating within a CoP has no relevance if the community itself does not have certain norms or practices, which are the ingredients that form a culture. Thus, the second example where Andrea sees culture as relevant to learning is a seemingly small, yet vital, step towards thinking socioculturally.

In the third finding, the shift from viewing learning as a product to a process relates to Sfard's discursive view, where cognitivist perspectives see learning as an object, while the sociocultural perspective views learning as an action. The objectification of learning gives finality to the process. Once acquired, there is a final product that has been achieved. In contrast, participation in action connotes a dynamic and never-ending process. Andrea's focus on learning as a list of tasks to be completed suggests that she didn't recognize the ongoing activity as the learning. Her reflection upon the process shows how she came to understand that everything that had to be done on the way to these products was the learning.

These three ideas are not the only aspects of sociocultural thinking, but do signify sociocultural thinking. If, as the conference theme states, we want to transform learning and empower learners, understanding the development of sociocultural ideas can help the LS accomplish these goals.

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Mathematical Argumentation and Proof – Supporting a Complex Cognitive Skill

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Abstract: During the last decades, research has provided evidence that handling mathematical argumentation and proof (MA&P) represents a complex cognitive skill, which requires various constituent skills. However, research on MA&P skills as well as their facilitation largely disregards this fact and effective means to foster the constituents and overall MA&P skills remain mainly unclear. Transferring research on the facilitation of complex cognitive skills from instructional design, two approaches may be effective: Fostering the constituents one by one respectively fostering them simultaneously. We therefore present an intervention study that takes a holistic approach on MA&P skills and their constituents, comparing a sequential (one-by-one) and an integrated (simultaneous) instructional approach to foster each constituent skill as well as students' overall MA&P skills. The results show that learners in the integrated condition and the sequential condition have very similar learning gains that differ only in their mathematical strategic knowledge, which is superior in the integrated condition.

Keywords: mathematics education, proof, argumentation, intervention, whole-task approach

Introduction

Reasoning, argumentation and proof are of special importance within the *proving science* mathematics. Therefore, research on mathematical argumentation and proof (MA&P) skills has been a long-term focus within mathematics education (Hanna, 2000). Most MA&P research, however, disregards the fact that MA&P is a complex cognitive skill integrating a variety of domain-general and domain-specific constituents, e.g. knowledge facets, sub-skills, and beliefs. A recent review on research on MA&P within mathematics education has shown that studies taking these constituents into account and conceptualizing MA&P skills in a holistic way are rare (Sommerhoff, Ufer, & Kollar, 2015). However, research on instructional design (Anderson, Reder, & Simon, 1996; Branch & Merrill, 2011; van Merriënboer & Kester, 2007) shows that acknowledging the complex structure of MA&P skills has important implications for how MA&P skills and their constituents should be supported and which instructional designs should be used. Knowing how to best foster MA&P skills and their constituents is important since research has repeatedly revealed students' severe problems with MA&P tasks (e.g. Weber, 2001). We therefore present an intervention study focusing on several constituents of MA&P skills, comparing a sequential and an integrated instructional approach to foster these within university mathematics.

MA&P as a complex cognitive skill

Research on complex cognitive skills, e.g. (information) problem solving, has become increasingly important in instructional design. Yet, in spite of several theoretical accounts and a multitude of studies on how complex skills can be effectively fostered in general, empirically validated approaches to foster MA&P skills are still scarce. However, most studies underline that acknowledging the constituents of the complex skill is essential for designing powerful learning environments.

Table 1: Constituents of MA&P skills investigated in the current study

Constituent	Characterization
Mathematical knowledge base	Basic conceptual and procedural knowledge in the field of mathematics (Ufer et al., 2008)
Methodological knowledge	Knowledge of the nature and the functions of proof as well as the acceptance criteria for a valid proof (Healy & Hoyles, 2000)
Mathematical strategic knowledge	Knowledge about cues within mathematical tasks and problems that indicate which concepts and representation systems can be used productively (Weber, 2001)
Problem solving strategies	Domain-general and domain-specific problem solving strategies (Schoenfeld, 1985)

MA&P skills represent a complex cognitive skill and up to now several constituents of MA&P skills have been identified and shown to be predictive for the success of MA&P processes (e.g. Chinnappan, Ekanayake, & Brown, 2011). In our study, we utilize a model that includes four main constituents of MA&P skills (Table 1). It is based on existing, models for geometry proofs (Chinnappan et al., 2011; Ufer, Heinze, & Reiss, 2008) as well as frameworks for general mathematical problem solving (Schoenfeld, 1985) and self-regulated learning (De Corte, Verschaffel, & Eynde, 2000).

Supporting mathematical argumentation and proof skills

Taking the perspective of MA&P skills being dependent on various constituents and thinking about an optimal way to facilitate these, at least two opposing strategies for the design of powerful instruction emerge: Supporting each constituent separately one-by-one (*sequential approach*) or handling all of these simultaneously (*integrated approach*). Although little research has been done on the promotion of constituents of MA&P skills, hints can be found in instructional design research. Within the last decades, instructional design researchers have debated about the effectiveness of part-task *vs.* whole-task approaches (Anderson et al., 1996; Branch & Merrill, 2011; Lim, Reiser, & Olina, 2009). Classical instructional design approaches assume the decomposability of complex tasks into less complex part-tasks and recommend the separate training of each of these less complex part-tasks. The decomposition theory from ACT-R (Anderson, 2002) even breaks down complex tasks to actions happening within milliseconds. The part-task approach is guided by the ideas that instruction on part-tasks is of higher instructional clarity for the students, that each part-task is easier to master and that the learning gains on the part-tasks transfer easily to learning gains on the overall task.

On the other hand, the whole-task approach (van Merriënboer & Kester, 2007) as well as the situated cognition approach (Brown, Collins, & Duguid, 1989) reject this atomization of tasks, provide evidence for the situatedness of learning, and point to difficulties that are associated with attempts to transfer from part-tasks to the overall task (Anderson et al., 1996). This implies teaching knowledge facets, sub-skills, attitudes, and beliefs constituting a complex cognitive skill in an integrated way (van Merriënboer & Kirschner, 2007).

Leveraging these two positions and transferring them back to MA&P skills and their constituents, we therefore contrast these two approaches empirically: A sequential approach*,* with students working on proof tasks with an explicit focus on only one of the required constituents at a time, compared to an integrated approach, with students working on proof tasks with a specific focus on multiple constituents at a time.

Aim and research question

The goal of the present intervention study is to explore the effects of an integrated and a sequential instructional approach on four constituents of MA&P skills (mathematical knowledge base, methodological knowledge, mathematical strategic knowledge, and problem solving strategies). We therefore investigated whether these approaches differ in their effects on students' knowledge and skills regarding these constituents. No *a priori* hypothesis was established regarding the greater effectiveness of each approach since theoretical arguments and evidence in support of both approaches exist (Lim et al., 2009). Yet, both approaches were expected to yield positive learning gains from pretest to posttest.

Methods

Study design, dependent variables and procedure

We used a quasi-experimental design for our study. The intervention was offered as a voluntary course for first year mathematics university students entitled "Mathematical proof: that's how you do it". It was scheduled between first and second semester and consisted of a pretest and a posttest as well as four two-hour intervention sessions across three consecutive days. The intervention consisted of two parallel courses representing the integrated condition and the sequential condition, respectively. Two instructors with prior experience in lecturing led the courses and switched after two units to eliminate instructor effects. Both courses covered the same content, the same tasks and time on task, although tasks and content were arranged in a different order.

During the intervention, students were provided with information on all four constituents by short presentations. Additionally, they were given a short list of prompts meant to enhance the analysis of tasks according to each constituent prior to the actual solving process (e.g. "Excerpt all important objects and properties from the task, explain these in your own words and compare them to the formal definition.", "Search the task for keywords that you know from other tasks. What methods did you use there?"). The instructor afterwards demonstrated the usage of the prompts for each of the constituents. All in all, students worked on eight tasks, and each task was analyzed regarding two constituents, solved and discussed with the instructor. Both groups received

guidance during their work on the tasks. For the sequential group, each session contained a presentation on one constituent as well as four tasks that the students analyzed regarding the same constituent. Each task was then picked up in another session for the analysis of a second constituent. Within the integrated condition, the presentations were divided into two larger blocks, so that most theory on each constituent was given in session 1 and only additional points were introduced in session 3. The students directly analyzed each task regarding two of the four constituents. In order to have the students of the integrated condition work two times on each task like the students in the sequential condition, tasks that had already been analyzed and solved were reconsidered briefly once more in this condition.

Instruments

The pretest and the posttest included self-designed scales assessing the constituents of MA&P skills on limits and infinite sums, a scale of four MA&P items, as well as control variables for inferential reasoning, metacognition, and scientific reasoning and argumentation (Gormally, Brickman, & Lutz, 2012; Inglis & Simpson, 2008; Schraw & Dennison, 1994). The MA&P items covered in the course and tests were closely related to a regular proof-oriented calculus course, but novel to the students in order to avoid bias by prior experience. The pretest and posttest were created using parallel items and contained open as well as closed items. The closed items were evaluated using mark-recognition software with a subsequent manual control of the recognition results. Two raters coded the open items following a theory-based coding scheme. The interrater reliability of the coders was $\kappa > .76$ ($M = .92$; $SD = .09$). The scales used in the both tests had an overall acceptable internal consistency of $\alpha_{\text{Mean}} = .70$ ($SD = .10$) with individual values ranging from $\alpha = .58$ (mathematical strategic knowledge; 4 items) to $\alpha = .81$ (problem solving strategies; 48 items). The results for all constituents were re-scaled to values between 0 (worst) and 1(best). Additionally all documents used by the participants were gathered throughout the intervention to analyze this process data later.

Sample

A total of 46 students (19 male, 27 female) participated in the study. The participants were first and second year mathematics students (first year: 36, second year: 5, no indication: 5). They can be assumed to have participated in the calculus I lecture and have had prior experience with proof-based real analysis. 24 and 22 students were assigned to the integrated and sequential condition, respectively. Several participating students had failed the exam of the calculus I course, thus the sample can be assumed to be slightly lower performing than average.

Findings

The pretest results verified that both conditions were comparable in their performance on the constituents prior to the intervention (Table 2, upper part). A Mann-Whitney U test indicated no significant differences between both conditions could be shown. Only methodological knowledge slightly approached significance ($U = 184.5$, $p = .078$). There were also no significant differences between the two conditions regarding the assessed control variables (mean final high school qualification grade, high school qualification grade in mathematics, inferential reasoning skills, metacognition, scientific reasoning and argumentation skills). Accordingly, they were not controlled for in the further analysis.

Table 2: Mean values for MA&P constituents obtained in the pre- and posttest

		Knowledge base		Methodological knowledge		Math-strategic knowledge		Problem solving strategies	
		M	SD	M	SD	M	SD	M	SD
Pretest	Sequential	0.32	0.17	0.42	0.16	0.34	0.17	0.53	0.15
	Integrated	0.39	0.16	0.51	0.18	0.39	0.17	0.58	0.11
Posttest	Sequential	0.43	0.21	0.57	0.16	0.59	0.17	0.66	0.13
	Integrated	0.48	0.13	0.61	0.16	0.70	0.18	0.71	0.10

The posttest results (Table 2, lower part) showed significant ($p < .001$) learning gains for both conditions and all constituents. Nevertheless, the longitudinal effects across groups for mathematical strategic knowledge ($d_C = 1.595$) and problem solving strategies ($d_C = 1.052$) were larger than for methodological knowledge ($d_C = 0.751$) and mathematical knowledge base ($d_C = 0.582$) although the same amount of time was spent on all constituents.

Comparing the results of the integrated and sequential condition in the posttest, a significant difference can only be found for mathematical strategic knowledge ($U = 164.5$, $p = .027$), in favor of the integrated group. All other comparisons between conditions were insignificant ($U > 179$, $p > .061$).

Conclusions and implications

The results of our study reveal that both instructional approaches differ less than implied by the theories promoting a part-task and a whole-task approach, respectively (Anderson et al., 1996; Branch & Merrill, 2011). Good arguments for both approaches exist and within this study, both approaches yielded comparable learning gains for the constituents of MA&P skills with the exception of mathematical strategic knowledge, which showed better learning outcomes for the integrated approach.

Remarkably, the results of our relatively short intervention study show large learning gains, especially for mathematical strategic knowledge and problem solving strategies. Large learning gains particularly for these two constituents are reasonable, because university instruction usually does not explicitly focus on these constituents so that little prior knowledge can be assumed. The absolute effect sizes, however, should be considered with care due to the lack of a proper control group, addressing e.g. re-testing biases or effects by the sheer engagement in proofs. Creating such a control group is challenging because approaches with students not doing proofs at all or practicing unguided both have drawbacks. Nevertheless, such a controlled study will be an important step to validate effect sizes of individual constituents. Ongoing evaluation of collected data will show the effect of the intervention on overall MA&P skills as well as overall MA&Ps relation to the constituents. The results will give further insights how to create an effective holistic approach to foster MA&P skills.

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Modelling Authenticity in Teaching and Learning Contexts: A Contribution to Theory Development and Empirical Investigation of the Construct

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Abstract: Authenticity as a concept is used in a multitude of settings and is linked to various − to some extent divergent − pedagogical ideas. This contribution proposes an interdisciplinary, literature-based conceptualisation of the term leading to the modelling of authenticity in teaching and learning contexts. The model can serve as a basis for designing further empirical surveys and educational interventions.

Keywords: authenticity, modelling, learning settings, education, authentication, interdisciplinary

"Authenticity is not brought into the classroom with the materials or the lesson plan, rather, it is a goal that the teacher and students have to work towards, consciously and constantly" (van Lier, 1996).

Introduction

'Authenticity' is a common term which is generally understandable in everyday life. However, with regard to academic contexts a discrepancy can be found between the term's use and its conceptual understanding in different academic disciplines. Furthermore, there is a research gap concerning theory development despite the fact that authenticity is frequently advocated in the design of learning settings as it is supposed to stimulate the learning process. Especially for learning outside the classroom the importance of an authentic educational setting is often emphasised (e.g. Engeln, 2004; Lave & Wenger, 1991). Therefore, the aim of this paper is to develop a model of authenticity based on a review of empirical and theoretical research literature. This permits a multidimensional approach to the concept thus allowing for an operationalisation appropriate to the general research discourse as well as future studies. We begin by developing a literature-based, interdisciplinary concept of authenticity and will then present our model as well as its importance for future research.

Conceptualisation of the term authenticity in educational contexts

We conceptualise the term taking into account perspectives from humanities as well as science teaching, and, in particular, the subject areas of geography education, history education and language teaching (first and foreign language). Our research process focusses on the databases PsychInfo, FIS, JSTORE and ERIC using the keywords 'authentic', 'authenticity', 'authentic teaching', 'authentic learning', 'situated learning' and 'real learning contexts'. It includes both empirical studies and theoretical papers written in English and German.

As a first result it became clear that the term 'authentic' is used differently in everyday communication compared to educational scientific discourses: in everyday communication the term 'authentic' is often used synonymously with the words 'real' or 'genuine'. In educational discourses, however, 'authentic' learning settings are mostly simulations of everyday or professional contexts (cf. Billett, 2012). To resolve this paradox, the term 'authenticity' has to be conceptualised differently. If one assumes a contrast between real-life and highly-structured learning arrangements, authenticity in subject learning can be seen as a continuum between these two poles: the more successful the staging of a real-life context, the higher the level of authenticity. For instance, in authentic learning settings everyday or professional-scientific contexts are simulated in order to give students an insight into these areas and, moreover, to foster transferable knowledge and student competences (e.g. Brown, Collins & Duguid, 1989; Mandl, Gruber & Renkl, 2002). Nevertheless, one can only speak of a simulation because in learning situations some kind of instructional implementation and thus dissociation from the contextual reference is always present.

The way in which authenticity is orchestrated differs strongly between the various subject areas. Nonetheless, it is possible to identify specific trends they all have in common, e.g. an approximation of the employed method and the material to everyday or professional actions (e.g. Gilmore, 2007; Monte-Sano & Reisman, 2015; Emden, 2011). Texts which are frequently seen as constituting authentic material are those which (a) are not specially written for classroom use, and (b) enable a scientific learning approach (for example original target-language literature in foreign language teaching, sources in history education, or measurements in geography education). Here, a close link to the subject-specific method is already discernible as a propaedeutic approach towards research practices is often intended. Hence, the learning settings and methods share features

with the domains knowledge and competences should be imparted about (Roth, 1995). Moreover, in foreign language teaching the premise is to integrate target cultures of native speaker communities in the classroom. However, critics refute the claim of authenticity regarding such learning settings and point out that an assimilation towards target language-cultural contexts (a) can never achieve a truly convincing simulation of native speaker language, and (b) the students' subjective perception of authenticity would suffer strongly from the "make-believe" (Decke-Cornill, 2004). Particularly in foreign language teaching it is recognised that the learner's perception of authenticity plays a central role (Breen 1985), meaning that learners evaluate a learning setting based on their beliefs, knowledge, interests, abilities and requirements (e.g. Widdowson, 1978; van Lier, 1996). This process is called 'authentication' and implies that learners engage in and appropriate (parts of a) learning setting in an interactive process with their peers and their surroundings (cf. van Lier 1996).

To summarise, authenticity in the sense of an educational construct can be defined as a characteristic of teaching and learning contexts which consists of transferring certain features of real life and professional contexts to learning environments. This simulation is negotiated along a continuum through the interaction between the designed learning environment and the actors within it. The aim of authentic teaching is to increase variables that are relevant to successful learning, such as motivation or interest, and to acquire transferable knowledge and domain-specific competences. Following this concept of authenticity, we will now present a model condensing different aspects of and showing the relevant cause-effect-relationships in authentic educational contexts.

Describing and explaining the model

Based on the findings from empirical educational-psychological and subject-based research, authenticity in teaching and learning contexts can be modelled in the following way (Figure 1):
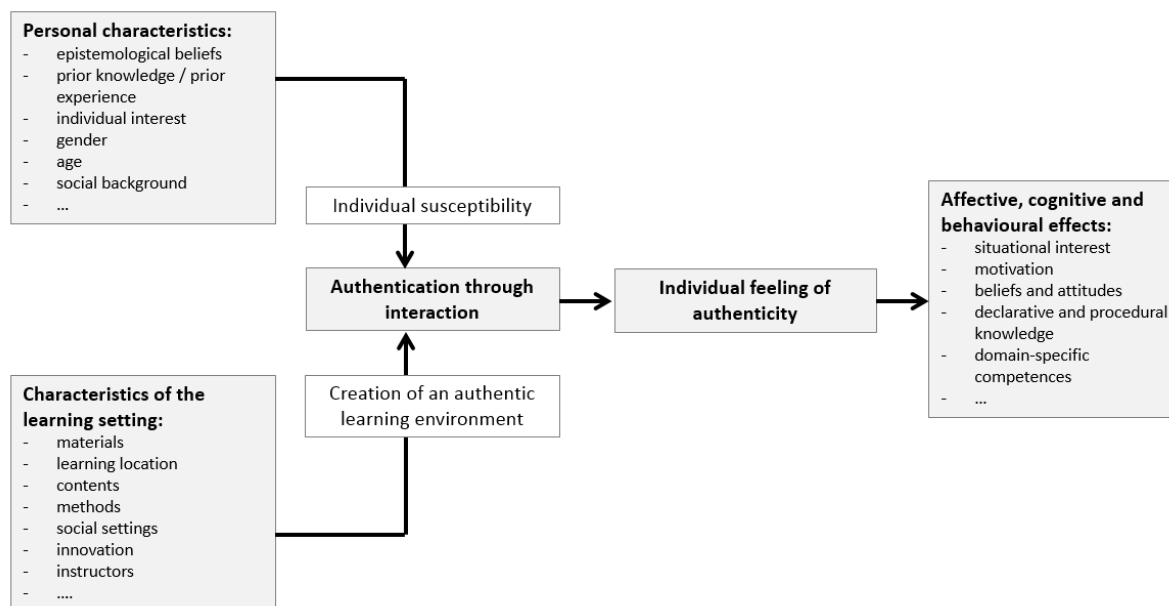
Figure 1. Model of authenticity in teaching and learning contexts.

The model consists of five components: (a) *personal characteristics*, (b) *characteristics of the learning setting*, (c) *authentication through interaction*, (d) an *individual feeling of authenticity* and (e) its *effects*. In terms of design the model is based on general progression schemas from educational psychology (e.g. for the development of interest; Krapp, 1998). While the personal characteristics and characteristics of the learning setting presented in the model are well-established in theoretical literature, empirical research on this domain is scarce. Also concerning the effects of an individual feeling of authenticity only a few studies exist (e.g. Glowinski & Bayrhuber, 2011; Engeln 2004; Peacock 1997) and evidence for relationships between the single variables are non-existent. Thus, the combination of all factors in one model constitutes an important step for theory development in authenticity and can serve as a basis for further empirical research. The model's single components, their relationship and empirical evidence therefor will be described in detail below.

a. The first two components in the model are the determining factors of authenticity in teaching and learning contexts, i.e. (a) *personal characteristics*, and (b) *characteristics of the learning setting*. The *personal characteristics* comprise the learner's individual dispositions, more precisely input factors such as individual interest and prior knowledge, which the learner brings into a potentially authentic teaching

and learning context. Such dispositions like, for example, individual interest, have proven to be important prerequisites for learning (e.g. Pawek, 2009) and influence the learner's susceptibility to the designed learning environment.

b. The *characteristics of the learning setting* describe the dimension of the model that can be manipulated and varied in a learning setting by the instructor or teacher. The characteristics should then converge with everyday and professional reality as closely as possible to create an authentic learning setting. Furthermore, central characteristics of authentic learning settings identified on the basis of literature in the subject areas are: material, learning location, contents, methods, social settings, innovation and instructor. Under 'materials' we subsume all media enabling a realistic content-based approach to the everyday or professional world. The 'learning location', in the sense of situated learning, permits insights into the work of 'communities of practitioners' (Lave & Wenger, 1991). The selection of 'contents' can be shaped in such a way, that themes from the respective 'real' reference context are brought to the fore. Problems and questions can be tackled with specific 'methods' and corresponding 'social settings' within authentic contexts. Examples in this regard include scientific methods (interpretation of historical sources, evaluation of measurements in geography or literature analysis in language teaching etc.) which can be imparted through inquiry- and task-based learning (Willis & Willis, 2007; Chinn & Malhotra, 2002) or the approach of 'cognitive apprenticeship' (Brown, Collins & Duguid, 1989). The characteristic 'innovation' means open questions or problems which are currently central to research or the subject of social controversies and to which the learners can contribute meaningfully. Finally, it is the 'instructors' responsibility to make authentic learning possible or provides access to the reference context. The arrangement of these characteristics takes place on a continuum according to their level of structuring.

c. The process of *authentication through interaction* involves actions in which interplay of characteristics of the person and the learning setting occurs including mediation between peers. Here, the interaction between determining factors and the learner's subjective perception of the learning setting plays a fundamental role (e.g. van Lier, 1996).

d. A *feeling of authenticity* would then be a feasible result of the authentication process. This feeling is subjective and can be determined through inquiries in the learner's perception of the learning setting and their attribution of relevance.

e. The perception of a learning situation as authentic may have *affective, cognitive and behavioural effects*, e.g. motivation, situational interest, domain-specific competences etc. (cf. Newmann, King & Carmichael, 2007), which influence the personal characteristics. In this respect a whole series of empirical studies in the area of Reach out Labs show that authentic, scientifically based learning environments have a positive temporal effect on students' situational interest (e.g. Engeln, 2004; Pawek; Glowinski & Bayrhuber, 2011). Furthermore, other studies showed that tasks, perceived as authentic, have a learning-conducive effect (Chavez, 1998) and authentic materials bring about an increase in learning motivation (Peacock, 1997; Chavez, 1998), reading and listening comprehension (cf. Young, 1993; Weyers 1999) as well as in writing skills (Purcell-Gates, Duke & Martineau, 2007).

Conclusion and implications

This contribution addresses two research gaps with respect to the authenticity of learning settings: (1) on the basis of a literature review it contributes to cross-discipline theory development connected with the concept of authenticity in educational contexts and names various characteristics which can have an impact on the authenticity of a teaching and learning setting. (2) The presented authenticity model is suitable for purposes of orientation in the design of interventions and surveys as it contains determinants influencing an individual feeling of authenticity. Thus, it can be used in future research to investigate possible effects of authentic learning settings (e.g. ask for the learner's perception of characteristics of a learning stetting via questionnaires in order to measure an individual feeling of authenticity; compare authentic conditions with non-authentic conditions to determine effects) and augment construct validity. The multidimensional model lays claim to applicability both to studies in the area of extracurricular learning and, with regard to educational questions, to desirable further research into the role of authenticity in teaching and learning contexts. The model already forms the basis for several research studies currently in progress at the Ruhr-Universität Bochum, Germany in the postgraduate programme "Communicating Sience in Reach out Labs".

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Acknowledgements

Fostering Collaborative Learning Through Knowledge Building Among Students With Low Academic Achievement

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Abstract: This study investigated whether students with low achievement were capable to collectively advance their online discourse in a knowledge-building environment. 37 students with low achievement from a 9th-grade Visual Arts course participated in the study. We analyzed students' online discourse. Findings indicated that students were able to collectively advance the community's discourse as they built on each others' ideas, generated theories, questions and metacognitive statements in a supportive knowledge-building environment augmented by reflective assessment. The study's findings have important implications for the design of technology-rich environments, and shed light on how teachers can use them to help learners to engage in productive collaborative inquiry.

Introduction

Much research in the learning sciences studies computer-supported collaborative learning (CSCL), which often involves metacognition (Stahl, 2002). However, little attention has been given to how students with low achievement perform in CSCL—e.g., students who score in the lowest third on central examinations.

In Hong Kong, students are very competitive and achievement oriented, even in primary schools. Secondary schools are classified in three bands—Band 1 (highest) through Band 3 (lowest)—based on achievement on a government examination, in Grade 6, of the majority of its students. Most students in Band-3 schools are low academic achievers, and are not adequately engaged with their schoolwork (Shen, Lee, & Tsai, 2007). Students with low achievement are often found to have limited metacognitive skill; they exhibit low interest and negative attitudes toward their learning. Helping students like these to engage in collaborative inquiry and to benefit from it is a great challenge for educators.

Recognizing these challenges, this study designed a knowledge-building environment augmented by reflective assessment which has been shown positively affected students' learning and performance. The study aimed to investigate whether students with low achievement were able to collectively improve their online discourse in a knowledge-building environment. This study was part of a larger study that investigated whether students with low achievement were capable to use reflective assessment to improve their attempt at knowledge building (Scardmalia, 2002), using an assessment tool, the Knowledge Connections Analyzer (KCA) (van Aalst et al., 2012). The following research questions were investigated: (1) What was the nature of the knowledge-building discourse? (2) To what extent did students improve their discourse?

Methods

Research context and participants

The study was conducted in a Band-3 school in Hong Kong; it was actually at the 10th percentile. The participants were 37 students in a 9th-grade class taking a visual-arts course; they were taught in Chinese. Students made inquiry into the topics *"What is art?" and "How to evaluate art?"* over five months, one lesson per week. The teacher had much experience teaching the visual arts, had taken a postgraduate course on knowledge building, and had used knowledge building in the classroom for approximately 8 years. The participating students had no previous experience with knowledge building.

Pedagogical design

The teacher used the following pedagogical process to familiarize the students with knowledge building, as described elsewhere in detail by van Aalst and Chan (2012); this process was adapted to the present context based on findings from a preliminary study: (1) *Helping students to develop inquiry, collaborative and metacognitive capabilities;* (2) *Deepening problem-centered inquiry in Knowledge Forum; and (3) Developing deep domain understanding and metacognitive skills through reflective assessment.* After working on Knowledge Forum to contribute a reasonable number of notes, students were guided to reflect on their notes by performing reflective assessment collectively and individually primarily with KCA data. To support productive reflection on the KCA data, students were provided with KCA prompt sheets that were both content-related and metacognitive, and

corresponded to each of the four questions in the KCA. Around each question of the KCA, the teacher and the first researcher, with the help of the KCA prompt sheets, created opportunities for student reflection. Small groups of student were asked to reflect on the KCA data, to identify problems in their online discourse, and to make further plans to address the problems.

Analysis and results

Data source in this study were computer notes students posted on Knowledge Forum. We analyzed the Knowledge Forum database using the inquiry thread analysis, followed by analysis of interactions and contributions within these inquiry threads. Then we report the results of characteristics of students' notes in three stages (Stage 1, Stage 2 and Stage 3), to evaluate the advancement of the online discourse.

Inquiry thread analysis

All computer notes except three unfinished notes (400 notes) created during 2.5 months were put into inquiry threads, yielding 18 inquiry threads. An inquiry thread is a sequence of notes that aim to address the same principal problem (Zhang et al., 2007). To check coding reliability of inquiry thread analysis, two raters independently completed the task on 40% of the notes. The inter-rater reliability was .80 (Cohen's kappa). Some threads involved most of the students as authors (e.g., #1, #3, #4, #7, #8, and #13), whereas others involved only a small number of authors; this suggests that some problems attract more attention from the community than others (Table 1).

Qualitative analysis of student interaction and contribution within inquiry threads

To characterize the students' interactions within and contributions to the discourse at a more granular level, we used a coding framework to code the notes in each inquiry thread. The development of the coding framework involved an iterative coding process of theory- and data-driven approaches. The coding schemes included three main categories of *questions, ideas* and *community,* and corresponding subcategories, and drew upon theoretical frameworks for social, cognitive and meta-cognitive processes of knowledge construction (van Aalst, 2009; Zhang et al., 2007). The coding framework and coding examples can be accessed online (http://kbc2.edu.hku.hk/ICLS2016coding.pdf). Two raters independently coded the notes from three inquiry threads ($n = 120$, 30%). The inter-rater reliability was .78 for questions, .78 for ideas, .79 for knowledge quality, and .77 for community (Cohen's kappas).

Results from coding the discourse in the inquiry threads are shown in Table 1. We selected 14 large inquiry threads and present the numbers of questions and ideas in them. Inquiry threads defined as large included more than ten notes. Generally, the results demonstrated in Table 1 are consistent with the classification of the inquiry threads as a whole and suggest that students created many new ideas and were involved in explanation-oriented discourse. For example, students wrote more notes with explanations than notes with simple claims (approximate 145 and 113, respectively, for most metacognitive statement were elaborated explanations). This result indicates that students engaged in a deep—and not superficial— knowledge building process. At the same time questions and statements that were more explanatory appeared in those threads that concerned explanatory issues.

Table 1 also shows that the students asked many metacognitive questions (53 notes), and contributed a reasonable number of metacognitive statements that included meta-discourse (48 notes) to reflect on progress and highlighted promising ideas or problems for further inquiry. All these data indicate that students invested much effort into reviewing and reflecting on the online discourse. At the same time, metacognitive questions and metacognitive statement appear more in threads that concerned explanatory issues. We further categorized students' contributions to their community. As shown in Table 1, 222 notes were classified as *depending inquiry*, and 40 notes were *synthesizing notes*. These results indicate a high frequency of responses to others' questions and ideas, most of which focused on conceptual advancement and at creasing a knowledge space of value to both the community as a whole and individuals.

Table 1: Number of different categories of questions, ideas and community in inquiry threads

	No. of notes	No. of writers	Questions			Ideas				Community			
			Notes raising factual questions	Notes raising explanatory questions	Notes raising metacognitive questions	New ideas	Simple claim	Elaborated explanation	Metacognitive statement	Lending support	Deepening inquiry	Regulating inquiry	Synthesizing notes
Total of the 17 threads	400	37	12	13	53	27	111	97	48	11	222	66	40
Mean (per thread)	23.35	13.24	.71	.82	3.24	1.67	6.76	6.00	4.53	0.65	13.53	3.94	4.12
SD	16.24	6.32	.77	1.07	3.13	1.96	4.34	6.09	5.91	0.86	10.58	3.58	5.44
#1	40	20	1	3	9	4	9	8	4	2	20	9	4
#2	15	10	0	1	5	2	3	1	2	1	6	5	2
#3	62	26	0	1	11	1	17	18	11	1	34	13	8
#4	28	17	1	0	4	5	7	4	4	1	16	6	2
#5	10	8	1	0	3	0	4	1	1	1	2	6	0
#6	21	15	0	3	1	4	4	2	4	1	11	4	2
#7	33	18	0	1	4	2	11	10	4	0	24	5	3
#8	43	19	0	2	4	4	8	6	16	0	17	6	16
#9	17	15	0	1	2	0	7	6	1	0	13	2	1
#10	14	13	1	0	2	0	6	3	0	0	5	2	0
#11	26	13	2	0	3	5	5	10	1	3	18	3	1
#13	41	19	2	2	2	0	14	20	1	1	33	2	1
#14	23	10	2	0	3	0	7	5	5	0	9	2	5
#16	11	10	1	0	0	0	6	3	3	0	9	0	1

Notes: Inquiry threads defined as large included at least ten notes each. #1 = relationship between good art and art is good; #2 = need of criteria of art; #3 = differences among works of art; #4 = principles of art; #5 = appearance and meaningfulness of art; #6 = role of art; #7 = criteria of art; #8 = fundamental criteria to judge art; #9 = eternity of art; #10 = reasons for judgment of art; #11 = creative ideas and second creation; #13 = art prices; #14 = defining art; #16 = art appraisal.

Table 2. Frequency and percentages of notes classified as questions, ideas, metacognition and rise-above during three stages

	Question		Idea		Metacognition				Rise-above	
					Metacognitive question		Metacognitive statement			
	f	%	f	%	f	%	f	%	f	%
Stage 1	11	8.59	26	20.31	15	11.72	1	0.78	0	0
Stage 2	2	1.56	45	35.16	20	15.63	11	8.59	7	5.47
Stage 3	1	0.78	26	20.31	19	14.84	43	33.59	39	30.47

Questioning, ideation, metacognition and rise-above

We further analyzed the characteristics of the students' notes in 14 large inquiry threads in three stages, each stage having an equivalent proportion of notes, to demonstrate the advancement of discourse. As the goal was to show the advancement of discourse, comparison analysis was conducted on explanation-seeking questions (questioning), explanations (ideation), metacognitive questions and statements (metacognition), and rise-above (synthesis). Table 2 shows the results for the three stages and compared them with the aggregated results for each stage. The frequency distributions for Stage 1 and Stage 2 differed significantly: $\chi^2(df = 4, N = 109) = 15.60$, $\phi = 0.38$. The effect size was moderate to large. The frequency distributions also differed significantly for Stage 2 and Stage 3 three, $\chi^2(df = 4, N = 167) = 31.56$, $\phi = 0.44$; a medium to large effect; and for Stage 1 and Stage 3, $\chi^2(df = 4, N = 142) = 53.00$, $\phi = 0.61$; that was a large effect size. The results indicate primarily that the students contributed more explanation-seeking questions in Stage 1 compared with any other stages, and that that they were mostly engaged in reflecting on and regulating their inquiry, and synthesizing their notes during Stage 3.

Conclusions

This study investigated whether students with low achievement were capable to collectively improve their attempt at knowledge building. During the knowledge-building process, students with low-achievement in this class, in a supportive knowledge-building environment, were indeed able to assume high-level responsibility to collectively accomplish knowledge-building discourse. They engaged in productive interactions and progressively advanced ideas in the communal space. In addition, the pedagogical design is accessible to students with low achievement. The design incorporated three components: (a) periodic tasks that promoted collaboration and reflection, (b) opportunities for reflecting assessment data collaboratively, and (c) the framing of discourse improvement as collective responsibility. Although this pedagogical design was developed for engaging low achieving students to collectively advance knowledge-building discourse, we believe that this design would have important implication for the design of technology-rich environments to support learners and shed light on how teachers can use them to help learners to gain benefits from collaborative inquiry.

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Acknowledgments

Supporting Planning and Conducting Experiments

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Abstract: In inquiry learning learners design and conduct experiments. Learners experience difficulties with the involved processes and need guidance to design useful experiments. To guide students in this we created a configurable experiment design tool that is usable in multiple domains. The tool was tested with two configurations; one with a CVS structure in which learners had to design at least three experimental trials before conducting their experiment, and one in which this was not required. In the current study secondary students designed and conducted experiments in an online lab about buoyancy and Archimedes' principle. Three conditions were compared in terms of students' conceptual knowledge gain. Students worked with one configuration of the tool, or with no tool. Results showed significant differences between conditions for lower prior knowledge students' learning gain about buoyancy.

Introduction

Inquiry learning stimulates learners to actively construct their own knowledge by means of doing investigations, allowing them to gain higher-order understandings, instead of passively absorbing information presented to them. Learners follow (part of an) inquiry cycle that comprises orienting on the topic of interest, formulating hypotheses and/or research questions, setting up and conducting experiments, drawing conclusions, and reflecting upon their inquiry (Pedaste et al., 2015). Moreover, inquiry learning promotes learners' autonomous working attitudes and inquiry skills, both of which are important educational objectives in current curricula worldwide; it also promotes a positive attitude towards learning, and it motivates them to acquire, integrate, and apply new knowledge (Edelson, Gordin, & Pea, 1999).

An important phase of inquiry learning is the investigation phase during which learners design and conduct experiments to test a hypothesis or answer a research question. Based on results from their experiments they analyse their data and draw conclusions accordingly. The experimentation phase thus builds a bridge between the hypothesis or research question and the analysis of the data.

However, learners find it difficult to design valuable experiments (de Jong & van Joolingen, 1998). It involves several processes and requires understanding of inquiry. They need to understand that they have to design experiments with which they can test their hypothesis or answer their research question. Often learners design experiments that do not comply with their hypothesis or research question, for instance by including variables that have nothing to do with it (de Jong & van Joolingen, 1998).

After selecting relevant variables, learners need to determine what to measure (dependent variable), vary (independent variable) and control for (controlled variable). Then they have to assign values to the independent and controlled variables. Learners often vary too many variables, which makes it difficult to draw correct conclusions because any effect that occurs may be due to a variety of influences. An effective strategy often applied by professional researchers is the Control of Variable Strategy (CVS) in which only one variable of interest is varied and all other variables are kept constant (Klahr & Nigam, 2004). CVS allows learners to draw conclusions from unconfounded experiments.

In order to successfully learn from experimentation learners must plan and apply systematic ways of designing experiments (de Jong & Njoo, 1992). However, research indicates that learners tend not to analyse a task or problem they have to solve, but to act immediately, without planning (Manlove, Lazonder, & de Jong, 2006). If learners do engage in planning, they often use unsystematic ways, which may cause them to struggle with the task (de Jong & van Joolingen, 1998).

Guiding learners in planning and conducting experiments helps them to design useful and systematic experiments from which they can derive knowledge (Zacharia et al., 2015). In computer supported inquiry learning environments some of the most often used forms of guidance are heuristics and tools. Heuristics are hints or suggestions about how to carry out assignments, actions, or learning processes. Examples of heuristics to direct learners to apply the CVS strategy are 'vary one thing at a time (VOTAT)', and 'control all other variables by using the same value across experimental trials' (Veermans, van Joolingen, & de Jong, 2006). Tools can transform or take over part of a task and thereby help learners accomplish tasks they would be unable to do on their own (de Jong, 2006). An example is a monitoring tool in which experiments are stored (Veermans, de Jong, & van Joolingen, 2000). Learners can replay conducted trials, and rearrange them in ascending or descending order to

be better able to compare results. It eliminates the difficulty of remembering conducted experimental trials, interpreting results, and simultaneously thinking of appropriate follow-up trials.

Based on heuristics and scaffolding elements that have shown to be effective for learning, an Experiment Design Tool (EDT) was developed that can be applied in different domains and configured so that it fits teachers' intentions with the inquiry learning activity. In the current study two configurations of the EDT were compared in terms of effectiveness regarding students' learning gain about buoyancy and Archimedes' principle. One configuration incorporated the CVS-strategy and required planning; learners were obliged to apply CVS and to plan multiple trials before conducting their experiment. The other configuration had a more exploratory character; learners were free to conduct their designed trials when they wanted to and were not obliged to apply CVS.

Method

In the current study students planned and conducted experiments in an online learning environment about buoyancy and Archimedes' Principle. Three learning environments were compared with different levels of support for planning and conducting experiments, but that were the same in all other aspects. In two learning environments students received additional support for planning and conducting experiments by means of one of the two configurations of the EDT. In the third learning environment students were not guided by an additional tool.

Participants

A total of 159 third grade pre-university students (aged 15) from three secondary schools in the Netherlands were randomly assigned to one of the conditions. After eliminating outliers and students that missed a session -e.g. one class missed a session because of an overlooked field trip- 104 students remained for analyses.

Learning environments

The three learning environments in which students worked were all structured in similar ways. They all consisted of instructions, research questions, a virtual lab, a mechanism to prepare experiments, a help button to retrieve domain information, and a conclusion text box. Upon entering the environment, instructions appeared explaining that the student had to design experiments and conduct those in a virtual lab in order to answer research questions. The environment contained a total of fourteen questions presented one by one. For each research question students had to design and conduct an experiment, and draw a conclusion accordingly. Once students had submitted a conclusion, a new research question appeared for which they again had to design and conduct an experiment.
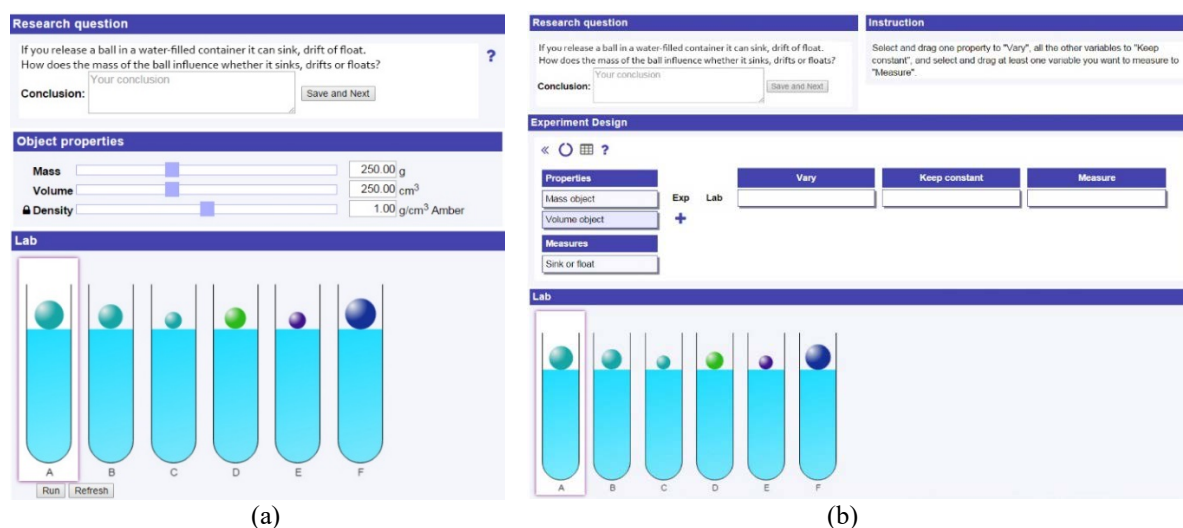
Figure 1. The learning environments for the (a) control group, and (b) EDT conditions.

The learning environments only differed in the support offered to students (Figure 1). The environment of the control condition did not contain a tool to help plan experiments. Experiments were prepared and conducted directly in the lab by means of sliders to adjust the values of the variables in the experiment.

The environments of the EDT conditions each contained one configuration of the EDT to guide the preparation and conduction of experiments. It provided students with structure in the form of a table that incorporated and emphasised three types of variables (independent, controlled and dependent). Students could select variables from a box and decide per variable if they wanted to vary it across experimental trials, keep it

constant, or measure it. After they specified the variables, they assigned values -within a restricted range- to the independent and controlled variables. For each independent variable they specified a different value per trial. For each controlled variable they assigned one value; the EDT automatically assigned that same value to all trials within the experiment. Results for the dependent variable could only be entered after the trials were conducted. In addition to preparing the experiments, the EDT offered a second table in which all the previously conducted trials were presented. In this table, variables could be sorted in ascending or descending order, making it easier to reach conclusions or decide if more trials or even experiments were required to answer the research question. At all times, students could see instructions about how to operate the EDT. The instructions were just-in-time and were based on students' actions. For example, when students started planning an experiment, they were instructed to drag and drop all properties to the boxes vary or keep constant, and to drag at least one variable to measure. The two configurations of the EDT differed in three aspects. In one configuration students were obliged to 1) apply CVS, 2) plan at least three trials before conducting experiments, and they 3) received different instructions that were congruent with these two aspects. In the other configuration students were able to, but not obliged to, do the same and they received instructions congruent with the configuration.

Assessment

Students' conceptual knowledge of buoyancy and Archimedes' principle was assessed both before and after the intervention with a parallel pre- and post-test. The test consisted of 58 open questions that measured students' understanding of the key concepts and principles of the topics in the virtual lab.

Procedure

The study was performed during four sessions of 50 to 60 minutes each, over a period of two and a half weeks. In the first session the students received instructions about what they were going to do. Thereafter they had half an hour to complete the pre-test, which was sufficient for all students to finish. Finally, they were randomly assigned to a condition, received instructions about the upcoming tasks, the learning environment was shown, and they could ask any question. During the second session students first received a booklet matching the condition they were assigned to and then individually worked with the learning environment behind a computer to learn about buoyancy. The booklet contained instructions about the tasks, and all the research questions they had to answer during the session. The third session was similar to the second session; students also worked with the learning environment but the topic of investigation was Archimedes' principle instead of buoyancy. During the fourth session students took the post-test and were informed about the purpose of the study.

Results

A significant conceptual knowledge learning gain was found in all conditions for buoyancy (control condition: n = 34, $Z = 3.226$, $p = .001$; exploratory EDT condition: n = 33, $Z = 3.302$, $p = .001$; more structured EDT condition: n = 37, $Z = 3.015$, $p = .003$) and for Archimedes' principle (control condition: n = 34, $Z = 3.554$, $p < .001$; exploratory EDT condition: n = 33, $Z = 2.943$, $p = .003$; more structured EDT condition: n = 37, $Z = 2.757$, $p = .006$) using Wilcoxon signed-rank tests. Independent-Samples Kruskal-Wallis Tests showed no significant differences between the conditions for both parts of the test (buoyancy: $H (2) = .253$, $p = .881$; Archimedes' principle: $H (2) = .651$, $p = .722$).

However, research shows that tools can be especially effective for low prior knowledge students. We divided students in two groups based on pre-test scores; one group included students with the 50% lowest scores and the other group included students with the 50% highest scores. Independent-Samples Kruskal-Wallis Tests demonstrated a significant difference in learning gain between conditions for lower prior knowledge students on buoyancy, $H (2) = 6.17$, $p = .046$, in favour of the exploratory EDT condition (control: $M = 7.17$, $SD = 5.68$; exploratory EDT: $M = 10.93$, $SD = 5.28$; more structured EDT: $M = 5.75$, $SD = 6.58$), but not for Archimedes' principle. Also, no significant difference was found for higher prior knowledge students.

Conclusions and implications

The current study showed a different effect of guidance for lower prior knowledge students, who performed better with guidance in the form of an exploratory EDT on the first domain, than for higher prior knowledge students, who did equally well with and without guidance, which is in line with other research. Higher prior knowledge students often demonstrate more well-structured, goal-oriented inquiry behaviour; they use more sophisticated strategies to induce knowledge and encounter less problems than lower prior knowledge students (Hmelo, Nagarajan, & Roger, 2000). Additional support for higher prior knowledge students has found to be redundant, because they already have sufficient knowledge to construct mental representations (Kalyuga, 2007).

Research about the level of support for lower prior knowledge students shows that they find it difficult to interpret support, and perform better when they first have the opportunity to explore the domain of interest by themselves rather than immediately starting with systematic ways of designing experiments. However, research also suggests that these learners benefit from more support because additional guidance helps overcome missing schemas and reduces working memory load (Roll, Briseno, Yee, & Welsh, 2014). Interestingly, the current study showed that lower prior knowledge learners performed best when they were guided by a tool, bút this effect was only found in the first domain and the tool had to be configured so that students could still explore the domain without too many restrictions. The different effect of guidance for buoyancy and Archimedes' principle might be explained by the level of difficulty of the two domains. Buoyancy -the first domain of experimentation- is generally regarded as easier than Archimedes' principle by students. We hypothesise that students received enough support to let them perform better on the tasks within buoyancy, whereas they may have needed additional support for the more difficult topic of Archimedes' principle. Future studies should focus on students' inquiry processes and the level and form of support they need in distinct domains with different levels of difficulty.

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Acknowledgment

Designing Technology for Learning:
How to Get from Disenfranchisement to Disinheritance and Why We Need to Go There

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Abstract: This paper describes ruptures in design practice and designed products that manifest as an experience of design that I call *disinheritance*. Disinheritance is the relationship a learner has to a designed tool or environment that makes the learner perceive it as not designed for them, not belonging to them. Disinheritance offers new ways of combining design-based interventions with ethnography about design in a "marginalized" part of the world, and is necessarily also concerned with economics, politics and how they shape design on a global scale. Building on Vygotsky's *cultural heritage* and Marx's *alienation,* the theory of *disinheritance* sets a new programmatic agenda for learning sciences research.

What's wrong with disenfranchisement?

In order to meet the agenda for this conference—to empower learners to design their social futures as they participate in the competitive global economy—we must broaden our scope of design and of how design relates to learning theory and to design practice in globally connected arenas. This paper offers an alternative for looking at how global flows produce new relationships to design for marginalized or disenfranchised groups of learners. As a word, disenfranchisement depicts the problems of poverty, necessity, and exclusion—problems constituted in gaps of access to and quality of learning environments that are magnified across global regions. Life and work in the developing world, what is dismissed as the Global South or *global periphery*, often entails learning work-arounds rather than dismantling oppressive systems that produce inequalties. Learners in so-called disenfranchised settings are capable of creatively framing problems to generate new ways of perceiving and addressing economically-imposed constraints. Disenfranchisement is a model of deprivation that fails to get at that ease of creatively seeing through constraints, what McDermott calls "the passion and ingenuity of whole persons with thick lives" (2010, p. 144).

My theory, *disinheritance,* offers an alternative framework for understanding that ingenuity: it articulates how the disenfranchised work within broken systems and accounts for how the social periphery can function as a space for recourse. The imperative is to explore the mental models for finding such clever work-arounds, a complex cognitive function that I call *disinheritance*. *Disinheritance* embraces the ambiguity of living under social structures that are beyond one's control while still practicing ways of getting by. The theory of *disinheritance* critiques inadequate and imprecise language such as "marginalization" or "peripheral," because the language characterizes social and political relations as spatial metaphors rather than perceptions of power and exclusion that can be negotiated and reforged. *Disinheritance* takes as a starting point an understanding of agency not as an automatic human capacity but as "a process in the making" (Dijk, De Bruijn, & Gewald, 2007) that arises from the reflexivity between the social conceptions of actors and the material conditions they live in. The active process of making agency can lead us to reinterpretations of "the periphery" that deemphasize the role of place and, as a corrective, put focus on a state of disinheritance as *sensory, perceptual, and cognitive* activity that allows people to weave around or work around the systems that undervalue them. The task for the learning sciences is to apply this to the design of pedagogical interventions and learning environments.

Disinheritance: A theoretical framework

Theories of learning have explained social and political inequalities of access in learning environments using spatial metaphors. Lave and Wenger's framework of a *community of practice* (1991) has been a cornerstone of scholarly discourse on how the social milieu shapes cognitive activity. Understanding processes and pathways to learning in communities calls for a mapping of how activities are regulated and consequently placed either at the center of the community or relegated to the periphery of the community's interests, through a process of legitimization or *legitimate peripheral participation*. This framework gives the impression that movement away from the periphery is the very dynamic of learning, but for many people on the periphery the notions of *center* or of *movement* are illusory.

The community of practice model was intended to describe how locally proximate groups reproduce themselves, but learning sciences research can not continue to overlook global phenomena such as economic stratification, postcolonial histories, race, gender, and broad exclusionary discourses on technological

empowerment—global forces that intersect with the local to shape how communities think of their practice. Indeed scholarship in science and technology studies (STS) emphasizes how the design of technology and the construction of scientific protocol are heavily influenced by global flows and ruptures (Appadurai 1990; Poppi 2003). Critiques of class, gender, and race have looked at identity and subjectivity as they are shaped by discourse and challenge our perceptions of how learning empowers the learner in contemporary socioeconomic contexts. The imagery of average learner who moves toward the center by negotiating, choosing and succeeding is "a neo-liberal dream of reinvention through education" (Walkerdine, 2003). In her contribution to the scholarship on situated learning/situated cognition, feminist learning scientist, Diane Celia Hodges, describes a process of alienation that she calls *dis-identification* (Hodges, 1998). Dis-identification captures how marginalized participants in a community of practice engage with the activities of a community of practice without developing the sense of being authentic members. While Hodges documents the importance of self-doubt as a form of agency and political consciousness, this paper is more interested in developing a theory about doubt in "the system" that I attribute to *disinheritance*.

With *disinheritance*, I juxtapose two conceptions mind and activity to which a more expansive view of global participation can be applied—*cultural heritage* and *alienation*—which draw from Lev Vygotsky and from Karl Marx. From the first, *cultural heritage,* I am interested in an expansive reading of the "culture" shared by learners which accounts for the geopolitcal and economic paths of exchange by which a learning technology designed in the United States ends up being an everyday part of life in Zimbabwe. Recall that Vygotsky (1997) describes cultural artifacts as "artificial stimuli-devices", tools mediating between subject and object, whose purpose is the intellectualization of behavior. The affordance of cultural artifacts is to encode social values into how things are perceived; but also to reframe or recontextualize problems. While these artifacts might be neutral in Vygotsky's theory of mediation, they are in practice created through tense social engagements that play out differently in the United States and in Zimbabwe. In the second conception of mind and activity, *alienation*, I draw on the socioeconomic disjunctures in this interconnected global "society" that produce unequal relationships to technology and to its design. The unevenness of relationships to technologies are ruptures or failures in the ability of technology to mediate learning and experience. They represent ripe opportunities to novel methodological approaches to design.

Ruptures in design: Cultural heritage and disinheritance

The golden standard of design practice—human-centered design or design thinking—invites the user to participate in design from the phase of conception to the development of a product. Designers of learning technologies, informed by learning theories such as distributed cognition, hold as an ideal that the interface of a technological tool created to assist learning will eventually become less obvious to the user. In the purview of learning technology design, technologies scaffold how we think with them by "fading into the background," what Pea (1993) ascribes to "distributed intelligence." The ideal is for technologies to become invisible or quiet mediators of cognitive transactions, yet in settings like Zimbabwe's economic crisis and other contexts in which the global poor learn to make-do, the technology, infrastructure, tools and artifacts that mediate activity are conspicuously visible because they fall in a critical state of dysfunction or disrepair. Global paths of distribution and the economic alienation of many local contexts from the source of a technology mean that protocols for specialized repair and planned obsolescence (*intentional* design features) are shaping the state of disrepair of technologies that learners encounter.

Disinheritance focuses on the materiality produced by global economic conditions that can be seen as a sheen or patina on designed things. When two classrooms—one in the United States and the other in Zimbabwe—are equipped with desktop computers, different experiences of design manifest because one classroom has funding for equipment updates and the other does not. The classroom with equipment that is allowed to fall into disrepair is a classroom with disinheritance. Where a flicker of the lights in a setting like the United States might be a noticeable but trivial anomaly, in Zimbabwe it would be a constant reminder of the collapsing economy and of failures of the nation-state to deliver infrastructure such as electricity. For the disinherited, the patina of everyday objects often becomes a corollary for the relationship the user has to the social hierarchies and access to participation in the global economy. The disconnect between the design process and the experience of the designed environment illuminates why unforeseen uses, the misuses and the dis-uses surprise designers even after human-centered design.

Disinheritance, then, is the process of leveraging as "cultural artifacts" alternative meanings that are generated through disconnections, disruptions and dysfunction (noise artifacts). In the section that follows, I discuss how learning sciences research methods can be created to capture disconnections in how designers and learners conceive of design. I outline how the theory of disinheritance informs pedagogical interventions, serves as a guide for the design of learning activities, and combines cross-sectional approaches to inquiry on learning.

From disinheritance to novel methods

A commitment to the critique inherent in disinheritance lends itself to methods that challenge assumptions about authorship in research and the final product of design-based research. The novelty in this approach to relating the theory to the methods is that the participants are the source of theorization, they are invited to do the analytical work and by doing so often break out of the dominant narrative about what learning needs a technology has been designed to address. In this section I outline my methodological approach to inviting users to design and allowing them to learn about and critique design thinking. The methods also invite learners to theorize about the learning challenges they face themselves. This is a double design intervention where a pedagogical change is introduced in an iterative manner and where the intervention equips the learners with skills that can empower them to design for themselves. This second act of the design-based intervention resembles Freirean talking circles because–it captures experience in the words of those experiencing it.

In two studies, I invited 33 Zimbabwean medical professionals to design technologies that can address a complex problem with social dynamics: the challenge of infant nourishment for HIV-positive mothers (Study 1); and the morning commute using informal transportation (Study 2). In both studies, participants were analyzing how technologies affect the livelihoods of those around them, exploring the social implications of technologies, and collaborating on creating new technologies that they see as social interventions. Both studies were set in Zimbabwe where the dysfunction, breakdown, and disorder of technologies and infrastructure are especially conspicuous and where these ruptures evoke a particularly vibrant material experience. The studies began with workshops where the participants worked in interdisciplinary design teams. They learned about design thinking process, and the value of storytelling and user-engagement in framing problems. The goal was for workshop participants to unpack how conceptions of the world coalesce around the broken, and dysfunctional technologies at the center of the two case studies. This objective called for dialogue with participants about their take on citizenship, modes of living, and how technologies shape their subjectivity. I augmented these personal narratives with rich ethnographic data and design-based research about transportation and infant care in Zimbabwe.

In Study 1 (Kabayadondo 2015), participants were prompted to create a prototype that would allow them to think about their invention in a structured way while also revealing the processes and conceptual blocks they encountered. I trace how the activity of prototyping helped the participant teams determine which design features must be built into their invention. I analysed the talk shaped around the prototype: the bids that participants made to their colleagues, the scaffolded thinking that they applied to the device, and how the content of their discussion was shaped by hopes (and pessimism) that innovation could ease the material conditions of the Zimbabwean crisis.

Study 2 outlined the disinheritance framework by focusing on the kombi, a large passenger vehicle appropriated in informal or illicit transportation for those unserved by formal bus services—kombis account for over half of the world's public transportation trips everyday (Cervero & Golub, 2007). Traditionally, large surveys, participant observation, and interviews have been used to understand informal transport. Taking a cognitive approach enriched the discourse on informality with accounts of the role the technology of the vehicle plays in shaping conceptions of the everyday. In their talking circles, the participants unearthed a spectrum of conflicting but co-existing realities for kombi passengers. They discussed the ambiguity of statuses such as "victim" or "beneficiary," opening up the possibility for passengers to simultaneously have agency and be vulnerable. As they constructed their model of the disinheritance created by the kombi, the participants flashed back and forth between multiple subjective stances, of themselves, of the partners they are designing with, and of the learners they are designing for. This ability to flash between subjective stances was a product of a fluid perception or *perceptual agency*, what Monson (2008) describes as the ability of musicians, for example, to lace in and out of hearing features in a complex musical composition. The combination of design and theorization revealed how learners construct agency out of ruptures and was methodologically lucrative for explaining how what on the surface appears to be disenfranchisement produces clever workarounds and ingenuity.

A new agenda for learning sciences

Learning sciences research has taken on the imperative to empower learners to go about learning through designing tools and environments that make that learning happen more smoothly or efficiently. As learning scientists who care about design, we are focused on technology that fades into the background. The reality is, however, that social conditions often lead to design being misused or disused—it is foregrounded in new forms of usability that provoke a rethinking of how learners relate to design. We need to understand that a cognitive process is going on when these new forms of usability arise. Learning technology tools are designed for their functionality, in a design process that seldom takes into account dysfunction, misuse, disrepair as sites for learning. The theory of disinheritance tries to capture how cognitive, sensuous, and perceptual responses to the dysfunction of technology lead to learning. The theory of disinheritance examines the learning that takes place

when the technology remains in the foreground. Disinheritance privileges the sensuous or perceptual experience of technology as it fails, surprises, misfires. The implications of taking design thinking to groups that don't get to participate in design process are that by allowing learners to learn about design and through design, we empower them to re-author theory about learning from their experience of what it is like to learn. In my reading, this is the next frontier of learning sciences research. If we are to reset the agenda for learning sciences research we are to do so by acknowledging the role, anticipating even, the consequences of disinheritance.

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Acknowledgments

Learning Environments to Facilitate Students' Regulation in Knowledge Building

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Abstract: We designed a project-based learning environment with Knowledge Forum to facilitate students' regulation of collaboration and examined how they developed regulation scripts through their experience. Jigsaw activity structure was implemented in the PBL design as a macro script. In addition, micro-scripts were provided for students to reflect on their group work and individual contribution in KF notes. A clustering analysis of students' regulation scripts revealed that they developed scripts through a variety of trajectories. Further case studies suggested: (1) that students develop their scripts when they recognized meaningful challenges, (2) that they construct scripts of socially shared regulation when they recognize epistemic challenge whereas they do co-regulation scripts when they recognize socio-emotional challenge.

Keywords: scripts, regulation of collaborative learning, epistemic challenge, socio-emotional challenge

Introduction

Scardamalia and Bereiter (2003) explain the nature of knowledge building as one of the prominent models of the knowledge-creation metaphor by referring to two modes of learning: the belief mode and the design mode. In the belief mode, learners are concerned with what they or others believe or ought to believe, namely, with the mental states of individuals. On the contrary, in the design mode, learners are concerned with the usefulness, adequacy, improvability, and developmental potential of ideas. Learners in the design mode should be aware of whether their ideas are good enough to solve the problems to be addressed, and how they should contribute to improving those ideas. Knowledge building is a social process that engages both modes of learning. The belief mode is used by learners to investigate the current state of their community knowledge level in order to highlight any problems. Learning in the design mode thus enables the creation of knowledge to solve problems. Exchange between the learning modes is iterative, such that learners continuously participate in social practices of knowledge creation, and individuals generate knowledge that not only directly contributes to the advancement of community knowledge but also determines how best to contribute to this advancement.

Although the knowledge-creation practices have been emphasized in many CSCL studies (Stahl, Koschmann, & Suthers, 2014), few studies have been focused on and examined students' regulation of their own collaboration (e.g., Järvelä & Hadwin, 2013). When contributing to a collaborative task, learners have to regulate themselves, others, and the group as a whole. In self-regulated learning, learners regulate their own learning to contribute to group performance, based on their individual perception of tasks and their strategic knowledge. In co-regulated learning—another layer of metacognition—learners also regulate themselves in relation to others. Each learner in a group monitors the task perception, goals, and standards of other group members and considers ways their actions and interactions influence one another and the task. In the final layer of metacognition, learners engaged in a collaborative task collectively regulate their group cognition: this is socially shared regulation of learning (SSRL). In SSRL, learners are collaboratively involved in the planning, monitoring, evaluation, and regulation of social, cognitive, and behavioral aspects of their learning.

A promising approach to support and develop students' regulation of their collaboration is scripting (Fischer, Kollar, Stegmann, & Wecker, 2013). In their script theory of guidance, Fischer et al. discussed dynamic relations between learners' internal collaboration scripts and external scripts as instructional support. The internal collaboration scripts are students' internal representations of how to conduct collaboration. The scripts are described from the abstract level ("play") down to very concrete action level ("scriptlets"). Learners are expected to develop their internal collaboration scripts through their experiences in collaboration and other instructional interventions. The external scripts are used to scaffold learners' engagement in their collaboration and lead them to more productive collaborative outcomes. For the external scripts to be effective to improve students' internal scripts, we have to avoid the situation of over-scripting (Dillenbourg, 2002). An external collaboration script is most effective for students to develop their own internal scripts when it is directed at the highest possible hierarchical level of internal script and subordinate components are already available to the learner. Miller and Hadwin (2015) propose a conceptual design of CSCL environment for helping students to learn to regulate their own group work providing external scripts and awareness tools. Few studies, however, have discussed how

students develop their internal regulation scripts through their collaborative learning experiences under such an environment.

In this study, therefore, we attempted to design Knowledge Forum for supporting students to develop their regulation scripts and examine how their scripts are developed through their experiences of collaboration. It was used as a digital portfolio where students collaboratively reflect on their face-to-face project-based learning with an ill-structured task from the perspective of regulation. As a macro script (i.e. external scripts which loosely orchestrates the engagement in PBL), jigsaw activity structure was implemented. Students were first divided into four different expert groups where they studied the same problem from four different perspectives. Then they further continued their collaboration in jigsaw groups where students who studied four different resources collaboratively worked on their ideas to solve the problem. Micro-scripts were implemented as question prompts to support students' reflection on their group progress and individual contribution. We assessed students' regulation scripts before and after their jigsaw group work and examined how their scripts were changed through their collaboration experiences through case studies.

Methods

Design description

Forty-eight university freshmen (24 female) took the course for learning how to manage their collaborative learning through participating in project-based learning. They were randomly divided into groups of four or five then given a task to propose new solutions to reduce wastes at convenience stores for conservation.

Students' group work was designed based on the jigsaw activity structure as a macro script. They were provided with four sets of documents related to their solution task. Then students for the same sets of documents gathered and discussed in expert groups (from week 1 to 4). After learning documents, they further continued their projects in jigsaw groups (from week 5 to 11) by integrating knowledge resources from the four sets of documents and searching for new information to create their solutions. In this jigsaw group work, we implemented micro-scripts for them to reflect on their collaboration at SRL, CoRL, and SSRL level in Knowledge Forum.

Before students started their group work in the jigsaw group work, a pre-questionnaire was conducted for evaluating students' internal scripts of regulating collaboration. Based on their experiences in the expert group, students were asked to describe their own evaluation of group work and individual contribution to it. During the jigsaw group work, students came to the classroom every week to discuss their work in progress and spend time for searching new resources and collaboratively integrating their ideas from different resources. At the end of class every week, students reported work in progress as a group note on Knowledge Forum and their individual evaluations on their group progress as "build-on" notes (Figure 1). When writing their group notes, scripts for planning, monitoring, evaluating and revising were provided as scaffolds in Knowledge Forum notes ("What was today's plan to do as a group?" "How much did you as a group achieve?" "Did you decide each individual's task(s) for the next week?" "Plan to do in the next class"). In their individual "build-on" notes, scripts for monitoring, evaluating and revising were provided for facilitating each student's involvement in her group work (e.g., "Was the goal shared among members?" "Were members aware of their own roles?" "Did you have rules facilitating group work? Did you follow them?"). Another post-questionnaire was again conducted as their reflection-on-action after the jigsaw group work.

Analysis plan

First, based on students' writing of collaboration in their group work in the pre- and post-questionnaire, we assessed each student's regulation script with respect to which aspects (planning, monitoring, and revising) and levels (SRL, CoRL, and SSRL) were represented. When a student referred to an aspect (planning, monitoring, or revising) at each level of regulation (SRL, CoRL, or SSRL) in her writing, we assigned 1 for that category, and we aggregated three numbers at each regulation level. So when students wrote all aspects at all levels, they were given 3–3–3. With this procedure, we coded students' pre-questionnaire as pre-script, and pre- and post-questionnaire collectively as post-script. Two authors (the first and the second) independently coded students' writing and reached 80% agreement. The disagreement was resolved through their discussion. After this assessment, we conducted a clustering analysis for categorizing students' scripts into different types.
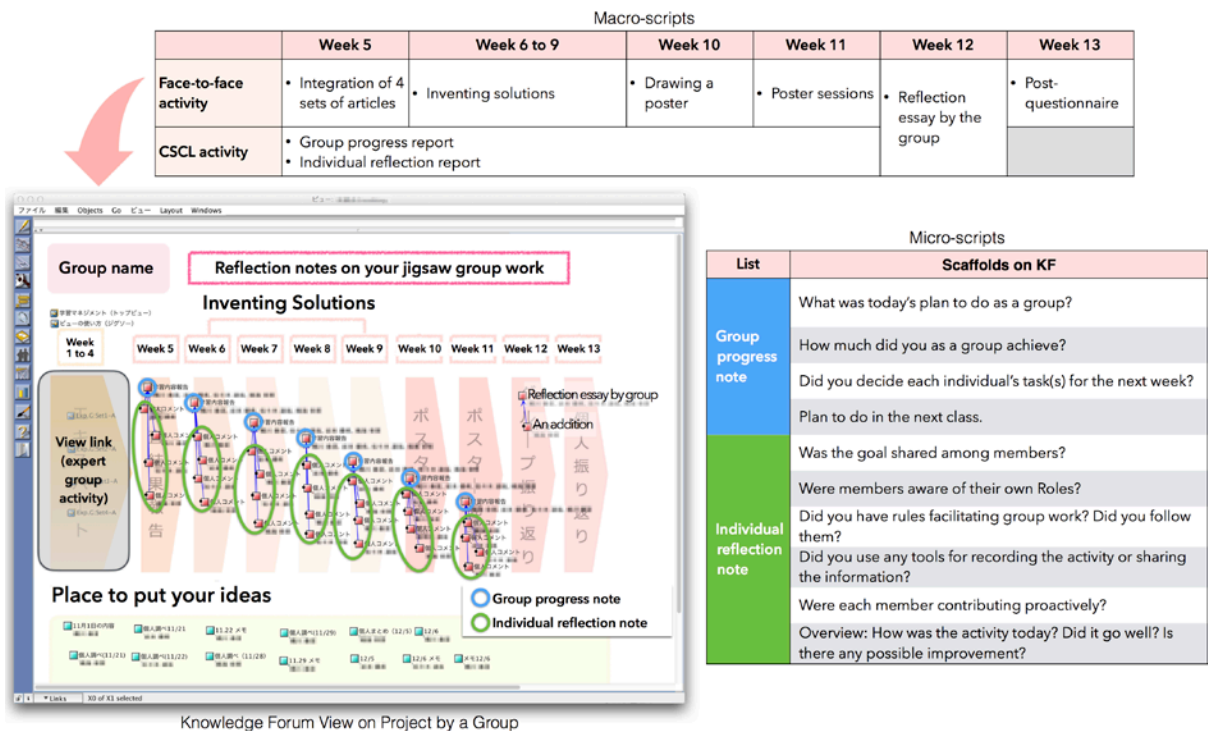
Figure 1. Jigsaw activity structure represented in Knowledge Forum
as macro script and scaffolds in KF notes as micro-scripts.

Second, to further examine how students constructed their regulation scripts through their experiences of jigsaw group work, we conducted case studies of students: (1) who did not change their scripts from the pre- to the post-questionnaire, (2) who successfully constructed their scripts across SRL, CoRL and SSRL, and (3) who constructed their scripts in different orientations based on the same socio-emotional challenge. In our case study, we constructed narratives of what challenges the students attempted to solve based on their group progress reports, individual reflection, and the mentors' field notes.

Results and discussion

Students' regulation scripts after their jigsaw group work

Forty-three students appropriately answered both the pre- and post-questionnaire. Thirty-nine students were found to construct new category of scripts in their post-questionnaire and the proportion was significant by Binominal test ($p < .01$). We further conducted a clustering analysis with Ward method for the forty-three students' post-scripts and divided them into the following five categories: (1) SSRL-oriented (N = 5), (2) SSRL-, CoRL- and SRL-oriented (N = 11), (3) insufficient (N = 8), (4) SRL-oriented (N = 7), and (5) CoRL- and SRL-oriented (N = 12). When they described more than two aspects of planning, monitoring, and revising at the level of regulation, students were identified as being oriented at a level of regulation (SRL, CoRL or SSRL).

Case studies: How students constructed their scripts through their experiences

As we expected, development trajectories of students' regulation scripts were various even within the same groups because of differences in students' pre-scripts and recognition of collaboration experiences. For examining how their pre-scripts and their experiences influenced students' construction of regulation scripts, we analyzed their group progress notes and individual reflection notes in Knowledge Forum during their jigsaw group work.

Why students' scripts were not changed

Among four students who did not manifest any change in their regulation scripts, two students (A1 and A3) worked in the same group. Their group progress reports revealed that they had an epistemic challenge that their group had not agreed on any solution ideas among members and failed to collect evidence to back up their solution. Whereas two other members (A2 and A4) described the problem and considered how to solve the epistemic

challenge by revising their regulation in their reflection notes, A1 and A3 did not show any notion of the problem in their notes.

How students could reconfigure their regulation scripts through engaging in their group challenges

In a group, three of four students successfully reconfigured their regulation scripts at SRL, CoRL and SSRL levels. In this group, they recognized an epistemic challenge in sharing their ideas among members because they decided to work separately as subgroups of two students each. In their individual reflection notes, they were so much concerned with this epistemic challenge by describing their group work from the perspective of goal and planning, monitoring, and revising.

How students' regulation scripts were reconfigured in different orientations

In groups of students who reconfigured their regulation scripts in different orientations, we found that students recognized different challenges (epistemic or socio-emotional) and did not share their recognition in the articulate ways. They did not discuss in their group work and report their challenges (or problems) in their group progress notes. Each individual recognized different challenges in their individual reflection notes. When they recognized epistemic challenges, they attempted to apply regulatory strategies at SSRL level. On the other hand, they did more individual (SRL or CoRL) regulatory strategies when they recognized the socio-emotional challenge.

Discussion

This study was aimed at investigating how students' regulation in collaboration could be facilitated by designing a learning environment with CSCL as a digital portfolio. Based on studies of regulation in collaboration (Järvelä & Hadwin, 2013) and script theory of guidance (Fischer et al., 2013), we designed activity structure as a macro-script and scaffolds in students' group progress report and individual reflection notes as micro-scripts. Results revealed that significantly more students reconfigured their regulation scripts through their collaboration experiences in this learning environment. Although the external scripts we designed were effective for students, further studies are needed for examining the effectiveness more rigorously. First, our assessment of students' regulation scripts was focused on aspects (planning, monitoring and revising) at three levels (SRL, CoRL, and SSRL) but not an elaboration of each script (i.e., play, scene, roles and scriptlets). We must further conduct studies of how hierarchical structure of regulation scripts is reconfigured through students' experiences in their collaboration. Second, from our case studies of students' group progress reports and individual reflection notes in Knowledge Forum every week, we found a hypothetical relationship between the reconfiguration of regulation scripts and types of challenges students faced in their collaboration. Results of our case studies suggest that students would reconfigure their regulation scripts at SSRL level when they recognized epistemic challenges and shared them among members. Although it is difficult to control kinds of challenges as a design element, we need to further consider how students' reports during collaboration can modify our design in progress.

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Resolving Disagreements in Evaluating Epistemic and Disciplinary Claims in Middle School Science

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Abstract: Supporting argumentation that fosters not only students' disciplinary engagement but also their epistemological development is of great importance in science education. Due to constraints of resources and designs, building "productive moments of uncertainty" (Manz, 2015) into the classroom to facilitate argumentation is challenging. This study addresses such challenge by analyzing how 6th graders resolve disagreements when evaluating epistemic and disciplinary claims. Preliminary findings suggest that talking about epistemic concerns without disciplinary engagement is not productive. Embedding epistemic practice in resolving disciplinary disagreements, however uncomplicated it may seem, would foster productive argumentation. Understanding what disagreements are challengingly resolvable and how both epistemic and disciplinary practices play a role in evaluating claims thus sheds needed light on designing effective learning environments that foster deep learning.

Introduction

Argumentation in the classroom empowers science learners. Through arguing with each other, students not only make sense of what they learn and gain conceptual understandings of science in a deeper way (Driver, Newton, & Osborne, 2000; McDonald & Kelly, 2011), but they are also appropriated into ways of talking and communicating about science (Lemke, 1990). Further, defending one's own ideas and persuading others exercise students into epistemic practices of coordinating evidence and claims and evaluating information, which is critical in learning science (Sandoval, Sodian, Koerber, & Wong, 2014; National Research Council, 2012).

As argumentation and epistemological development are highly intertwined, supporting argumentation about epistemic concerns is of great importance in science education. It is not easy, though, as science has long been taught as a set of established facts (Millar & Osborne, 1998). Manz (2015, p. 28) thus proposes that teachers should build "productive moments of uncertainty" into classroom activities to facilitate their epistemic practices. It is still a challenge due to constraints of resources and designs (e.g., Berland & McNeil, 2010).

We report here on an ongoing study that addresses such challenge. Drawing on Manz's (2015) frame of contesting and resolving disagreements, we analyze science learning in a 6th-grade classroom geared towards coordinating claims and evidence to understand how arguing with different claims and resources shape students' perceptions of uncertainty and their epistemic practices. Two research questions guided our analysis: What disagreements do students face when evaluating claims? How do they resolve these disagreements?

Methods

Participants and data sources

This study took place in a 6th-grade classroom in a K-6 laboratory school at a public university in metropolitan Los Angeles during the 2013–2014 school year. This classroom has 48 students (21 boys and 27 girls), whose ethnicity largely mirrors the school demography: 36% Caucasian, 20% Hispanic, 9% Asian, 7% African-American, and 28% Multi-ethnic. The student age is 11.4 years on average. A science teacher, Ms. Hill, taught two units during the school year in this classroom, one on earth science and another on astronomy. As we worked closely with her throughout the year, the instruction was organized around a set of activities in which students were asked to evaluate claims or prompted to propose claims to be evaluated.

We videotaped the entire year of science instruction, including 68 videos (approx. 80 hours). While videotaping the lessons, we also observed the setting and took field notes in order to document the contextual information that could not be recorded through the camera.

Analytic approach

Our approach to understanding classroom practices was guided by principles of interaction analysis (Jordan & Henderson, 1995). First, we reviewed the science lessons entirely for several times to get a general sense of the classroom ecologies. Major shifts of instructional topics and participant structures in each lesson were indexed. We then identified episodes that involve student-to-teacher or student-to-student argumentation. Third, we

transcribed these episodes in ATLAS.ti. Codes focused on evaluating claims (e.g., "it is not accurate because") and resolving disagreements (e.g., "do you agree with that") were emerged from constant comparison. Finally, we brought these codes back to the videos to confirm the typicality or atypicality of the instances.

Findings and discussion

Disciplinary arguments in resolving epistemic disagreements

We worked with Ms. Hill on organizing a series of discussion that focused on evaluating claims. We thought it would be helpful to establish, from the onset, shared norms that guide students' work (Ryu & Sandoval, 2012; Driver, Newton, & Osborne, 2000). We thus asked students how to prove a claim is accurate. Their initial criteria were collected on a worksheet and sorted out by frequency. We then put highly frequent ideas (more than 10 times) into a category of methods that can prove a claim is accurate, and the rest another category of those that cannot. Ms. Hill then launched a discussion in which students talked about whether one particular criterion should stay in the "accurate" column or be moved to the "not accurate" column. The discussion lasted for three lessons, through which students agreed upon a final list of criteria.

The episode we present here took place in the second lesson when Ms. Hill guided students to discuss whether "using common sense" could prove a claim is accurate. The first three arguers talked about the usefulness of common sense at a highly abstract level. The fourth student, Luke, used a concrete example, for the first time in this discussion, about unicorns to illustrate his idea. This "unicorns" example was picked up for several times in the argumentation that followed, as shown in the following transcription segments (the line number are from the transcript of the entire discussion not included here, unicorns mentioned in bold).

26	Luke:	Well, I disagree with you because when you said about how… Like you
27		need common sense to make an accurate claim, not necessarily because if
28		you don't have any sense, yes there's chance you can… **Like you can say**
29		**that, you know, unicorns are real.** But there's also a chance when you
30		don't use your sense, you just go straight by evidence, you know like hard,
31		tech evidence that will support your claim then you're gonna get an
32		accurate one.

73	Gary:	Eh, also I do agree with you also. ((Gary turns to look at Tina.))
74		Em, because they do make pretty far-fetched ideas that like, em, like are
75		true but also a lot, em, some of the time are also like not true. **Like a**
76		**scientist can say that like unicorns wearing flat hats.**

97	Sarah:	Well, I think that even though common sense is a little bit hazy and there
98		is a lot of ideas that come up, like every year, that seem out of blue, like,
99		"no that can never happen" but… They sort of have gone through thoughts
100		to thoughts processes and being able to connect and see how that would
101		work. **But like Gary said, like unicorns wear flat hats and run around**
102		**England last year, that is not using common sense, because I mean**
103		**there's history and there is no witnesses of unicorns running out last**
104		**year and…** Yeah.

140	Melissa:	**You can use common sense that does not have to do with unicorns, I**
141		**can say like Pluto is a planet and use my common sense to reason that**
142		**out.** But Pluto is not a planet, I mean, you know it makes sense to you, but
143		it may not make sense to others.

These four arguments provide an interesting lens into how students resolved epistemic disagreements. First, Luke used the unicorn as an example to back up his argument that common sense is not useful in proving a claim is accurate. Gary picked it up to argue, contrarily, that even though scientists may make breakthroughs that go against common sense, sometimes discoveries that do not fit with common sense are actually not true, so common sense can be a criterion. Sarah supported Gary and stated that common sense can be useful in evaluating the reliability of certain claims. Melissa, differing from the previous three, mentioned unicorn merely to shift the disciplinary matter to Pluto. Second, although they used the unicorn for opposite positions, their arguments were built upon that of each other. For example, Gary's idea involved Luke's "unicorns are real" and pushed it further into "unicorns wearing flat hats" in order to exemplify his comment about scientists' "pretty far-fetched ideas."

Sarah, moreover, gave the story a concrete context ("run around England last year") to demonstrate her point that using common sense would work. Third, Melissa's shifting from unicorns to Pluto is worth noting, because whether Pluto is a planet was actually a recent debate in science community. By inviting arguers to think about a more "scientific" problem that resulted in a surprising conclusion, Melissa rebutted Sarah's idea that common sense could be used to evaluate claim reliability.

This example indicates the difficulty of dealing with stand-alone epistemic claims. When resolving disagreements in this episode, students tended to provide concrete cases to facilitate their discussion. The "productive" in Manz's (2015) moments of uncertainty thus entails disciplinary engagement instead of talking solely about epistemics. It was "unicorns," so to speak, that greatly advanced students' arguments in this episode. As Hofer (2000) revealed that personal epistemologies are dependent upon disciplinary knowledge, we argue further, in line with Duschl (2008), that conceptual and epistemic understandings could not be separated.

Epistemic arguments in resolving disciplinary disagreements

After the whole-class discussion described in the previous section, the students agreed upon a set of criteria about how to prove a claim is accurate (e.g., gathering information from multiple sources, experiment for multiple times, reasonable arguments that make sense). In order to exercise students into using these criteria for their own projects, Ms. Hill and I decided to show students an example. We used "how hot is Sun" as a leading question, and asked students to make a claim about it and finding evidence to prove its accuracy. We had doubts about whether this question was too easy, as students all had their laptops in class with Internet access, while the answer to this question was, we assumed, not controversial at all. But we still posed it because we merely wanted students to go through the procedures of using their *own* criteria to make and evaluate a claim.

Students were asked to select evidence and make a claim as homework and reported and discuss their claims in a whole-class setting the next day. What surprised us in this discussion is, though we assumed that there was little room for argumentation, as the question was easy to search a solid answer for, students did argue. As they reported different temperatures for parts of the Sun (e.g., the core, the surface, the chromosphere), when Ms. Hill pushed them to reach a consensus, they had conflicting ideas about which number(s) they should report in their claim. The following transcript documents but one segment of a prolonged debate (about 16 minutes).

94	Susan:	I think it should be the core because that is the Sun.
95	Ms. Hill:	((Talking to Luke)) The average? Okay…
96	Mike:	It can't be the average!
97	Luke:	So it's like the whole Sun together…
98 99	Ms. Hill:	Okay, hold on, now we have the average, all of them, and the highest and the lowest, okay, so…
100 101	Ian:	I think we should do the layers, atmosphere and stuff, and also we can average.
102	Ms. Hill:	So now we're combining? How's that sound?
		((Several lines omitted here.))
108 109	Ian:	I think we should say like, the core is this hot, the chromosphere is this hot…
110	Ms. Hill:	List all of them?
111	Ian:	And, and the average is this hot.
112	Ms. Hill:	Does everyone agree with that?
113 114	William:	I don't know about the average now. I mean…we've already put all of the information.
115	Gary:	Yeah, well, but the average tells you what the whole Sun is.
116 117 118	William:	If you just say the Sun has multiple layers with varying temperatures, and you say nothing else, then you can put the average, but I don't think you need to put it now.

In this interchange, six students were arguing about how to report the temperature of the Sun. Susan thought the core represented the Sun, so the temperature of the core should be enough (#94). Luke and Gary argued that the average should be reported as it represented the whole Sun (#97, #115). Ian proposed that they should report the temperature of each layer (#100–101, #108–109). William, lastly, doubted the value of reporting

an average because it seemed to be redundant information (#113–114, #116–118). These students were arguing directly with each other, while Ms. Hill revoiced student ideas (#98–99) and pressed for consensus (#102, #106–107, #112) to advance argumentation (Michaels, O'Connor, & Resnick, 2008).

Although the question may seem easy to answer, these arguments touched on some epistemic concerns that are much more critical than knowing how hot the Sun exactly is. Susan, Luke, Gary and Ian were arguing about what part (the core, the average of all parts, all the layers, etc.) represents the Sun and, more precisely, what counts as legitimate knowledge about the Sun. William's doubt further tackle the validity of knowledge representations (i.e. whether the average is redundant). All of these participating students were thinking about not only what they knew, but also means of knowing and representing knowledge. This shows that seemingly undemanding questions like "how hot is the sun" could yield productive argumentation provided that the teacher makes epistemic concerns explicit and students accountable for their ideas about them. Our study thus expands on Engle and Conant's (2002) work and suggests that epistemic practice is useful in problematizing subject matter and creating resolvable uncertainty.

Conclusions and significance

Our study addresses a problem in argument-based learning: how to create "productive moments of uncertainty" (Manz, 2015) to engage students in arguing with each other and resolving disagreements? The first example in this paper suggests that talking about epistemic concerns without disciplinary engagement is not productive. The second one, on the other hand, shows that embedding epistemic practice in resolving disciplinary disagreements, however uncomplicated it may seem, would foster productive argumentation.

These findings join the conference theme and speak to the interests of ICLS members. Resolving disagreements that involve both disciplinary and epistemic practices empower students to evaluate not only what they know but also the means of knowing. Understanding what disagreements are challengingly resolvable and how both practices play a role in the evaluation thus sheds needed light on designing effective learning environments that foster deep learning.

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Tracking Student Teachers' Technology-Enhanced Collaborative Problem Solving: Combining Objective Assessment Data With Subjective Verbal Reporting

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Abstract: In spite of increasing interest, technology-enhanced formative assessment practices reflecting 21st century skills are not yet much studied, particularly in teacher education context. Also, studies that combine both objective and subjective data around these practices are still rare. This study responds to these challenges in exploration of student teachers' collaborative problem solving (CPS) processes. Relevant events in CPS tasks are tracked through process data acquired via ATC21S™ portal, and complemented with students' interpretations of these processes as cued retrospective reports. The broader aim is to provide student teachers with hands-on experiences of using novel, technology-enhanced formative assessment systems for 21st century skills. It is hypothesised that familiarity with these practices will guide student teachers to be more open toward formative, technology-enhanced assessment culture as they move into professional practice as teachers.

Introduction

Despite recent policy initiatives calling for 21st century skills, such as collaboration, collaborative problem solving, communication and critical thinking, current assessment practices often only focus on students' academic outcomes (Strijbos, 2011). However, to develop 21st century skills assessment strategies should go beyond testing students' factual knowledge and capture the less concrete themes that underlie the key skills defined for 21st century learning (Binkley et al., 2012; Kong et al., 2014).

Formative assessment, as assessment for learning (Black & Wiliam, 2009; Strijbos, 2011), is seen as a key feature of the 21st century learning environments (Redecker & Johannessen, 2013). It is argued that learners need substantial, regular and meaningful feedback during the learning process, enabled by formative assessment, and teachers, in turn, need the feedback to better orchestrate the learning processes according to the evidence provided (Redecker & Johannessen, 2013). However, formative assessment in the context of 21st century skills is a challenging and time-consuming task and may therefore be facilitated with technology and instruments developed to promote such activities as collaboration (Strijbos, 2011; van Aalst, 2013). Technology-enhanced assessment tools and systems that can be used flexibly, will not burden students or teachers, and that will enable constant interchange are therefore seen vital (e.g., Griffin & Care, 2015).

As changing society sets novel demands for schools in terms of learning and assessment, teacher training programs need to reflect these changes. Therefore, to contribute to agency change in this regard, teacher education students play a central role. As teachers-to-be, it is imperative that they recognise the equal importance of academic achievements as well as 21st century skills as learning outcomes (Kong, et al., 2014). Assessment practices tend to have strong influence on the direction of student learning and influence developing pedagogical practices. When teachers-to-be gain familiarity with the novel, innovative, technology-enhanced assessment practices, it is assumed that they will be open to this new learner-centred and formative assessment culture, which they will then bring along when they enter schools as teacher graduates (Binkley et al., 2012; Kong et al., 2014).

Collaborative learning and collaborative problem solving

Even though collaboration is regarded as one of the most crucial skills for learning and is already a part of today's learning environments, the assessment practices for collaborative learning have remained relatively vague (Strijbos, 2011). Assessment practices do not always reflect collaborative learning in a way that takes into account the complexity of cognitive, social and motivational factors as they occur over the collaborative process (Kumar, Gress, Hadwin & Winne, 2010). In addition, a general set of indicators with which to assess the quality of collaborative activities, or upon which to compare students' collaborative learning activities, is often lacking (Strijbos, 2011).

Consequently, collaborative problem solving (CPS), a specific type of collaboration, which conjoins critical thinking, problem solving, communication and collaboration (Griffin & Care, 2015; Griffin, McGaw, & Care, 2012), has received increasing interest as one of the central 21st century skills suitable for formative assessment. In short, CPS is defined as a joint activity between dyads or small groups to transform a current problem state into a desired goal state (Hesse, Care, Buder, Sassenberg & Griffin, 2015). Typically, CPS is organized through the use of directly observable verbal and nonverbal signals. That is, to work successfully, participants need to communicate, exchange, and share in the process of identifying the parts of the problem; interpret the connections between the parts and relationships between action and effect (i.e. rules); and propose generalisations in search for a shared solution (Hesse et al., 2015). This "side effect" of externalization makes CPS a visible and measurable activity, which, in contrast to individual problem solving, may make CPS a more teachable skill (Hesse et al., 2015).

Measurable CPS competency may be seen as the capacity of an individual learner to engage effectively in the joint and shared activity of problem solving. CPS skills can be divided into a set of sub-skills that comprise five broad social and cognitive capacities. These capacities may overlap between different stages of a CPS activity (Hesse et al., 2015) and include: social skills (participation, perspective-taking and social regulation), which are about managing participants (including oneself), and which refer to the "collaborative" aspect of CPS; and cognitive skills (task regulation and knowledge building), which are about managing the tasks at hand, and refer to the "problem-solving" aspect of CPS. These measurable skills are considered essential for successful CPS activity.

The assessment portal developed in the ATC21S™ project (Griffin & Care, 2015; Griffin et al., 2012) is one recent example of a technology-enhanced formative assessment approach that focuses on assessing more generic and transversal skills. The project explored new, technology-enhanced ways of assessing CPS skills and linked them to teaching interventions designed to deepen learning and move students to higher skill levels (Griffin & Care, 2015; Csapo, Ainley, Bennett, Latour, & Law, 2012). The ATC21S™ project built on the ideas of the developmental model of learning (Vygotsky, 1978); thus, its primary goal was to maximise the developmental progression of individuals' skills, such as those in CPS (Griffin et al., 2012). During the ATC21S™ project, a web-based, formative assessment portal for assessing CPS skills was developed at the Assessment Research Centre at the University of Melbourne.

In spite of increasing interest, technology-enhanced formative assessment practices reflecting 21st century skills are not yet much studied, particularly in teacher education context. Also, studies that compare methods based on objective and subjective data in this context, are still rare. This study responds to these challenges. Focus not only on the outcomes of CPS activity, but also the (collective) route to these outcomes from the learner perspective is important. Current technologies are typically inadequate to the task of analysing the contents of communication during the chat, and so the focus has been on placement (and occurrence) of chat actions in the CPS process (Care, Griffin, Scoular, Awwal, & Zoanetti, 2015). To acquire a deeper understanding of students' collaborative efforts in the course of CPS, a process-tracing method (van Gog, Paas, van Merrienboer & Witte, 2005) is proposed as a complementary method. Process-tracing methods produce data such as verbal reports, that can be applied for obtaining information that enables drawing inferences about the cognitive processes that underlie problem solving performance (Cooke, 1994; van Gog, Paas, van Merrienboer & Witte, 2005). In this study, the method is extended to cover not only the cognitive but also the social processes related to CPS.

Accordingly, the aim of this study is: (1) to compare process data acquired through the ATC21S™ portal to individual students' verbal reports on the process; and (2) to examine whether congruence between process and verbal data varies according to person and task characteristics.

Methods

Participants
The sub-study is part of a four-year research project that aims to promote student teachers' CPS and socially-shared regulation of learning (SSRL) skills and competencies as well as attitudes towards the use of ICT in teaching and learning. The research described here is an ongoing study, conducted during Autumn 2015. The participants are students ($n = 20$) in their second year of the four-year master-level teacher education program at a Finnish university.

Tasks
Pairs of students completed one bundle of assessment tasks of ATC21S™ portal. The bundle comprised four tasks in the science and math domains, related both to curriculum content and to generic skills. The assessment tasks

are complex game-like tasks, constructed to have the characteristics of problems that require true collaboration and are related to everyday teaching and learning (Care et al., 2015). Some of the tasks are content-dependent, while others are content-free and, the tasks also vary from symmetric to asymmetric (Care et al., 2015). Specifically, the tasks are designed for a student pair (Students A and B), who are expected to communicate only through an online chat interface. In this sub-study the bundle comprised following tasks: "Laughing Clowns" and "Olive Oil", which are content-free tasks, and "Plant growth" and "Small pyramids" which are content-dependent. Laughing Clowns is a symmetric task whereas the other three were designed asymmetric. Symmetric refers to the characteristic that both students within a collaborative pair are presented with the same stimulus content and actionable artefacts within the online task space; with asymmetric referring to the characteristic that each student within a pair is presented with different information and different actionable artefacts. To complete the bundle lasted approximately 60-90 minutes.

Objective assessment data

Students' work in the ATC21S™ portal was assessed individually, with the scoring based on their actions which included movement of artefacts, and the occurrence of chat to collaborate. Students also completed a brief reflective questionnaire as part of the online process. Students' completion of the assessment tasks generated log file data. The data generated were captured in a process data file, and patterns in these data were then automatically coded as indicators of the CPS elements (i.e. social and cognitive), producing reports ("Learning readiness profiles") on students' social and cognitive skill levels (Adams et al., 2015; Hesse et al., 2015). In addition, CamStudio™ software (see http://camstudio.org) was used for the recording of all the screen activity during the CPS sessions on the ATC21S™ portal.

Process-tracing data

To obtain a subjective account on the CPS processes, the process-tracing method as cued retrospective reporting (CRR) (e.g., van Gog et al., 2005; Jarodzka, Scheiter, Gerjets, & van Gog, 2010) was used. In short, CRR is defined as a verbal reporting procedure, in which study participants are invited to verbalise their thought processes during the task performance retrospectively, based on a cue or cues of their performance (see e.g., Jarodzka et al., 2010). With verbal reporting the aim is to make explicit the CPS process in terms of students' self-monitoring of *why* and *how* they took the actions, especially as a student pair. In this study, CRR interview was cued with the activity data (i.e. mouse operations, chat discussion) recorded during the ATC21S™ portal session. The CRR sessions were videotaped. The sessions took approximately one hour.

Analysis and expected outcomes

CRR resulted in qualitative accounts as retrospective reports concerning the cognitive and social processes of CPS from the perspective of an individual student. In-depth content and process analysis under the proposed CPS framework by Hesse and colleagues (2015) is being applied to the CRR data in studying the students' interpretations of their collaborative efforts during the problem solving activity. The aim is to compare the process data obtained via the ATC21S™ portal to individual students' verbal reports on the process and analyse for congruence. Congruence findings are being interrogated with regard to CPS success of the pair and characteristics of the task. To track and make visible the shared routes of successful CPS processes and their relevant events route maps of objective assessment data acquired via the ATC21S™ portal will be notated by the subjective verbal data. It is hypothesised that there will be relatively small skill level differences across student pairs due to the strict selection procedure of the teacher education students in Finland. At the conference, final results will be presented through route maps enriched with data examples.

Conclusions and implications

As previously mentioned, the recent international trend to modify curriculum and instruction to more adequately reflect 21st century learning poses new challenges in terms of assessment. For example, instead of considering collaboration merely as a learning method, it should be seen as general human competence to be assessed in its own right (van Aalst, 2013). Together with studying the underlying processes pertaining to (successful) CPS activities of student teachers, the ongoing sub-study is expected to provide student teachers with hands-on experiences of utilizing novel technology-enhanced assessment systems for 21st century skills. From a broader perspective, it is expected that these experiences may activate teacher education students' awareness of 21st century skills and most crucially, of novel assessment practices reflecting these encounters. Since teachers in Finland are considered pedagogical experts with significant decision-making authority in the application of core curriculum and assessment (see also Darling-Hammond, 2012), this might be a critical next step. Based on this

relatively small sample sub-study, later stages in the project are being designed to accumulate data with repeated and enriched objective and subjective methods with comparable, but larger, groups of teacher education students.

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Acknowledgments

Conceptualizing Authenticity and Relevance of Science Education in Interactional Terms

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Abstract: Authenticity and relevance are two terms that are often mentioned when criticizing the content and practice of science education in school. This paper examines the meaning of authenticity and relevance in science education from an interactional perspective. Particularly, it compares and contrasts authenticity with productive disciplinary engagement, and relevance with expansive framing. We then use this comparison to discuss the tension between maintaining accountability to the discipline and fostering students' agency and authority; a tension that is not sufficiently addressed in science education literature that addresses the conceptualization of authenticity and relevance. We suggest a research agenda that aims to resolve this tension by problematizing and articulating in fine detail the theoretical meaning of productive disciplinary engagement and expansive framing for science classrooms that are deeply immersed in authentic scientific practices and discourse.

Keywords: science education, teaching, learning, authenticity, relevance, interaction

Relevance and authenticity in science education

Since the beginning of the 20th century, science educators have been concerned with questions about which topics should be taught in science classrooms and what activities should students engage in while learning these topics (Meltzer & Otero, 2015). Authenticity and relevance are two terms that are often mentioned in current debates concerning these issues (e.g., Osborne & Dillon, 2008). Relevance was traditionally considered to be personally and societally driven, and as a central attribute of science education that can be productively applied in daily life decisions and future careers (Hurd, 1998). In their review of the meaning of the term relevance in science education, Stuckey, Hofstein, Mamlok-Naaman, and Eilks (2013) pointed to four main sources of relevance: (1) students' interest, (2) students' understanding of issues related to their lives; (3) issues of personal importance or need; and (4) issues with real-life effects on individuals and society. They described the first and second sources of relevance as driven by meaningfulness, and the third and fourth as driven by consequences (personal, societal and vocational). Interestingly, relevance to the content and to the epistemological and cultural nature of STEM disciplines has not been explicitly considered in the discussion of the relevance of science education, though in our opinion, it should.

Authenticity was traditionally considered to be disciplinary driven, reflecting the desire to simulate, in the classroom, "real" scientific practices, with the epistemological and reasoning aspects that such practices entail (e.g., Chinn & Malhotra, 2002). However, recent discussions of authenticity in science education argue implicitly, and often explicitly, for students' and teachers' agency in determining what authenticity means, and talk about authenticity as emerging from the interaction between canonical science, teachers and students (Rahm, Miller, Hartley, & Moore, 2003) or about positioning learners in collaborative social contexts so as to explore *their own* scientific questions (Calabrese-Barton, 1998; Rivera Maulucci, Brown, Grey, & Sullivan, 2014). Hence, if the discussion of relevance started from students' agency and went on to gradually include society as legitimate agents in defining what is relevant science education, an opposite trend is apparent in the case of authenticity, the discourse of which started from the canonical disciplines as the main determining agent, and gradually came to include students, teachers and society as legitimate agents in determining what authentic scientific practice in science classroom means.

When considered this way, the boundaries between relevance and authenticity of science education become blurred, the two concepts seem to complement one another, and the meanings of both seem to emerge from the interactions between the canonical STEM disciplines, the students, the teachers, and the society in which all these agents function. This paper examines the constructs of authenticity and relevance from an interactional perspective, comparing and contrasting them, respectively, with two related interactional constructs suggested by the late Randy Engle to describe productive classroom practices: productive disciplinary engagement (Engle & Conant, 2002) and expansive framing (Engle, 2006).

Productive disciplinary engagement and expansive framing

Randi Engle and colleagues examined social framing in classrooms, focusing on classroom discussions. Engle and Conant (2002) coined the term *productive disciplinary engagement* (PDE) to theoretically describe a specific type of student engagement that "combines, moment-by-moment, interactional aspects of student engagement with ideas of what constitutes productive discourse in a content domain" (p. 400). To explain the sense in which discussions are productive, Engle defined an additional theoretical construct—*expansive framing*. Engle argued that transfer is more likely to occur when learning contexts are socially framed by the teacher as part of a broader ongoing intellectual conversation in which students are actively involved. Engle termed this framing "expansive framing", as opposed to "bounded framing" with respect to the setting (time, place) and roles of the participants (Engle, 2006).

Drawing parallels

The engagement of students in what constitutes productive discourse in a content domain (i.e., PDE) is certainly consistent with engaging students in "real" scientific practices, which is the central principle of the traditional take on authenticity in science education. The question is whether we can regard PDE as an interactional parallel of authenticity, and if so, what is gained by this parallelism. The answer is complex. Rahm et al. (2003) wrote that "the focus on designing and establishing authentic science learning environments and tasks has neglected to ask what authenticity means, to whom, and according to whom" (p. 738). The same problematizing applies also, to some extent, to productive disciplinary engagement. Namely, a fair question would be to ask what *productivity* means, to whom, and according to whom. Yet, we would argue that thinking of authenticity in the science classroom as PDE allows us to better articulate the problem presented by Rahm and her colleagues, shifting the focus of our attention from the list of topics and practices that constitute authentic science education to the students' actual engagement with these topics and practices. Such refocusing explicates an unresolved tension between fostering accountability to the discipline, while maintaining students' authority over the ideas that are being discussed (see for example Engle & Faux, 2006).

To highlight the importance of addressing this tension, let us consider the perspective of authenticity that Buxton (2006) refers to as the "youth-center perspective on authenticity", and which she considers to be the extreme alternative to the canonical science perspective on authenticity. According to the youth-center perspective, learning is authentic only when its starting point is the student's desires, interests and needs. Yet studies that adopt this perspective are usually conducted in informal education settings, such as enrichment programs that target young children from families with multiple socio-economic related problems (e.g., Calabrese-Barton, 1998). In this context it is very easy to accept the domination of students' needs and interest over disciplinary demands; however, when considering science education at the advanced high school levels, accountability to the discipline is as crucial as is fostering students' agency and authority. This tension has not been explicitly and deeply considered in the treatment of authenticity in science education. We argue that the interactional lens that PDE offers can, at least potentially, lead to a more accurate and stronger conceptualisation of authenticity. In the next sections we elaborate how examining authenticity in science education through an interactional lens, namely considering it as a case of PDE and articulating what productivity in learning science means, to whom, and according to whom, can also contribute to the development of the theoretical and operational definitions of PDE.

Another parallel we wish to draw is between relevance and expansive framing. We argue that expansive framing articulates the construct of relevance in interactional terms and grounds it in classroom practice. Here again, the power of the interactional perspective is in focusing our attention on the engagement of students. Instead of debating the list of topics and activities that should be part of a relevant science curriculum, it draws our attention to the way in which these topics and activities are being used by teachers in their classrooms. Such refocusing suggests that the explicit links that science teachers are able to make between topics and activities in the official curriculum and the world outside of the immediate classroom reality, are at least as influential in creating a sense of relevance in their students as are the actual topics that are formally being taught. Just as the notion of expansive framing deepens and enriches our understanding of productive disciplinary engagement, the notion of relevance can add and enrich our understanding of authenticity.

Research agenda

Engle and Conant (2002) wrote that "productive disciplinary engagement can be fostered by designing learning environments that support (a) problematizing subject matter, (b) giving students authority to address such problems, (c) holding students accountable to others and to shared disciplinary norms, and (d) providing students with relevant resources" (p. 399). Although we agree with these design principles, we argue that to be able to truly

address the tension between students' authority and accountability to the discipline, we must problematize and examine in fine detail attempts to apply PDE design principles to the instruction and learning of science in contexts in which accountability to the discipline is crucial (e.g., science at the honors and advanced high school levels as well as undergraduate levels). Such contexts emphasize the need to articulate the disciplinary specificity and multidimensionality of the terms productive and engagement in PDE.

Engle and Conant suggested that "what constitutes productive depends on the discipline, the specific task and topic, and where students are when they begin addressing a problem" (p. 403). We suggest that in science classrooms that are immersed in authentic scientific practices and discourse, such productivity should be manifested by (1) conceptual and epistemological development, (2) development of scientific creativity and self-efficacy, and (3) identity construction as a person, citizen and future professional. We also agree with Engle and Conant that "evidence for student engagement can best be seen by analyzing students' discourse" (p. 402), but argue, as in the case of productivity, that we should better articulate what we are searching for. Specifically, we look for discourse markers that reflect (1) specific positioning of students and teachers with regard to each other, the task and the content, (2) deeply meaningful use of disciplinary concepts and habits of thought, and (3) social, personal, deeply affective, and future-oriented engagement with scientific content (Kapon, forthcoming; Levrini, Fantini, Pecori, Tasquier, & Levin, 2015). In our consideration of expansive framing, we are therefore interested not only in examining how the teacher frames the interaction for the student, but also how the student frames it, and the degree to which these frames overlap and demonstrate deep intersubjectivity (Wertsch, 1984).

Concrete examples

Levrini et al. (2015) identified forms of productive complexities that intrinsically characterize scientific practices and discourse in modern physics. Such complexities allow content to be problematized in a productive way for students. Specifically, they "educationally reconstructed" (Duit, Gropengießer, & Kattmann, 2005) the secondary school curriculum on thermodynamics to embody the following attributes: (1) Multi-perspectiveness – the same physics content was analyzed from two different perspectives (the macroscopic and microscopic approaches to studying thermodynamics), each characterized by a specific approach to the content. (2) Multi-dimensionality – the two approaches were analyzed and compared according to different dimensions involved in physics, i.e. their conceptual, experimental and formal implications, as well as their philosophical-epistemological peculiarities. (3) Longitudinality – the approaches to modeling systems and processes used in the thermodynamics unit were systematically compared with models used in theories previously studied by the students (classical mechanics and special relativity).

Levrini et al. (2015) analyzed data gathered from an extended intervention that implemented the designed curriculum in a 12th grade class of 20 students. They identified five discursive markers used to determine the student's progress in making the learned content relevant on a personal level and to its conceptual understanding. These markers include expressions that are (1) personal "signatures", i.e. idiosyncratic expressions involving personal tastes and purposes, (2) grounded in the discipline, (3) thick, in the sense that they involve a metacognitive and epistemological dimension, (4) non-incidental, in the sense that they are used consistently throughout classroom activities, and (5) carriers of social relationships that position the student within the classroom community.

Kapon (forthcoming) examined the engagement and learning of a group of eight 11th and 12th grade students while working in their school laboratory on long-term (18 month) open-ended research projects in physics. All eight students had the same project advisor: a physics teacher who is a member of a research community of teacher-researchers that associates several schools ("Acheret Center," 2006). Analysis revealed not only the development of the students' understanding and mastering of content and skills, but also identified discursive markers that highlight their progress towards the internalization of scientific habits of thought such as (1) spontaneous use of scientific standards of evaluation, (2) tendency to refine thought through model-measurement interactions, (3) persistence, (4) sensitivity to scientific aesthetics, and (5) self-efficacy with regard to scientific practices and procedures. These learning gains were connected to the particular nature of mentorship that the students received. The discourse between the students and the advisor positioned both students and advisor in a *joint* inquiry, like that of research apprenticeship, in which the expansive framing by the advisor aimed to relate the students' activities in the school laboratory to "real" science. The advisor explicitly cultivated students' interest and agency with regard to science, and nurtured their creativity, even when this cultivation meant *temporarily* compromising accountability to the discipline.

The discourse markers mentioned above (Kapon, forthcoming; Levrini et al., 2015) articulate the notion of authentic engagement with a scientific discipline and in so doing they further develop the concept of PDE. Specifically, while the term *productive* in PDE refers only to disciplinary productivity, its markers are very

generic, whereas our discourse markers are deeply grounded in the discipline. Our markers are also sensitive to the authenticity of the engagement from the students' perspective and thus articulate the way in which authenticity and relevance emerge from the interaction between the discipline, the students, the teachers, and the society in which they function.

Conclusion

In this paper we argued that re-conceptualizing the theoretical meaning of authenticity and relevance in interactional terms—particularly by drawing parallels between authenticity and productive disciplinary engagement and between relevance and expansive framing—articulates a tension between accountability to the discipline and fostering students' agency and authority. We suggested a research agenda that aims to resolve this tension by problematizing and articulating, in fine detail, the theoretical meaning of productive disciplinary engagement and expansive framing for science classrooms that are deeply immersed in authentic scientific practices and discourse.

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Developing Argument Skills Through the SOCRATES Learning Environment

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Abstract: The SOCRATES web-based learning environment, which aims to support the development of argument skills, is described here. Also, a study (in progress) is described where 5th graders (11 year olds) engaged (a) in electronic argumentive dialogs with classmates who held an opposing view on the topic, and (b) in some evidence-focused reflective activities, based on transcriptions of their dialogs, in the context of the SOCRATES learning environment. Participants' epistemic cognition, epistemic emotions and argument skills are examined.

Introduction

Engagement in argument from evidence features as one of the fundamental objectives of science education throughout the K-12 range, from kindergarten through grade 12 (The Next Generation Science Standards, 2013). There is a general consensus that there is a need to move away from practices that support the mere transmission of facts to students for consumption, to practices that promote scientific thinking.

Various approaches have been developed to help students learn how to participate in scientific argumentation with mixed results (Zohar & Nemet, 2002). Some efforts to support argumentation focused on teaching students the structure of a "good" argument, based on Toulmin's argumentation model, (Mc-Neill et al., 2006; Sampson & Clark, 2009; Zohar & Nemet, 2002). Yet, the modest gains of instruction to support argumentation (Osborne, Erduran & Simon, 2004; Zohar & Nemet, 2002) point to the challenge of supporting the development of scientific argumentation and to the need for further research to gain a better understanding on how to support students to develop the ability to engage in skilled argumentation. Some other efforts to support argumentation focused on offering professional development to teachers (Osborne, Simon, Christodoulou, Howell-Richardson, & Richardson, 2013) and studying teachers' practices in order to gain an understanding of what kind of practices support scientific argumentation (McNeill, Pimentela, & Strauss, 2013; Ryu & Sandoval, 2012). Yet, the work of Osborne et al. (2013) showed that relying solely on teachers, without any particular curriculum, is not always a successful means to promote students' argumentation.

Besides direct teaching and offering traineeship to teachers to support students' argument skills, computer supported collaborative activities have been employed to support students' argument skills (Bell & Linn, 2000). Iordanou and Constantinou (2015) developed the SOCRATES web-based learning environment which supports the development of students' argument skills through engagement in electronic argumentation and scaffolding. Students have the opportunity to engage in electronic argumentation, through a chat tool that is embedded in the learning environment, and then reflect on the product of their argumentation using electronic scaffold sheets. The SOCRATES learning environment supports both students' ability to construct counterarguments and their ability to employ evidence to support their claims and critique. Students are not directly asked to use evidence in their arguments; they are asked instead to reflect on whether they had used evidence in their arguments when engaged in a dialog with peers and to revise their arguments, in respect to employing evidence to back up their claims. Reflection is facilitated by having participants arguing on the computer, through instant messaging software, which has the benefit of providing an immediately available, permanent record of the discourse for participants to reflect on, in contrast to the conditions of real-time verbal discourse.

In the work of Iordanou and Constantinou (2014) the SOCRATES learning environment was employed to support pre-service teachers' argument skills. 66 Junior (third-year) students who attended an undergraduate program in Education engaged in an argument-based intervention in the context of the SOCRATES learning environment over 13 sessions. Same-side peers collaborated in that study in arguing on the computer against successive pairs of peers on the opposing side of an issue on the topic of Climate Change and engaged in explicit reflective activities on the use of evidence. In this study meta-level awareness regarding the use of evidence in discourse was supported by having same-side peers collaborating in arguing on the computer against successive pairs of peers on the opposing side of an issue on the topic of Climate Change and by engaging in explicit reflective activities on the use of evidence. Results showed that by the end of the intervention participants exhibited significant advances both in their skill of producing evidence-based arguments and counterarguments and regarding the accuracy of the evidence used. Advances were also observed at the meta-level, reflecting at least implicit understanding that using evidence is an important goal of argumentation. Another group of pre-service

teachers, who studied about the role of evidence in science in the context of regular curriculum and served as a control condition, did not exhibit comparable advances in the use of evidence in argumentation.

In order to gain a deeper understanding of the process of development Iordanou and Constantinou (2015) examined high school students while engaging in argumentive and reflective activities in the context of SOCRATES learning environment, using the microgenetic method. The aim of this study was to examine how students used evidence in argumentation when they engaged in argumentive and reflective activities in the context of a web-based learning environment. Sixteen 11th graders, working with a partner, engaged (a) in electronic argumentive dialogs with classmates who held an opposing view on the topic, and (b) in some evidence-focused reflective activities, based on transcriptions of their dialogs. Another 16 11th graders, who studied the data base in the learning environment but did not engage in argumentive discourse activity, served in a comparison condition. Students who engaged in an evidence-focused dialogic intervention increased the use of evidence in their dialogs, used more evidence that functioned to weaken opponents' claims and used more accurate evidence. Experimental condition students exhibited also gains in meta-level communication about the use of evidence in dialog over the course of intervention dialogs. Analysis of participants' dialogs over the course of the intervention was particularly insightful in revealing considerable gains in evidence use in argumentation after participants engaged in reflective activities about their dialogs. This finding suggests that reflective activities on evidence use might be an important feature of the intervention that supported the development of students' ability of using overall more evidence in argumentation and particularly evidence which functioned to critique other's position.

The present study

In the present study we extend previous work by examining participants' epistemic beliefs and epistemic emotions while they engage in an argument-based intervention in the context of the SOCRATES learning environment. Martinovski and Mao (2009) point to the cognition-emotion interface by maintaining that emotions serve as an argumentation engine. The category of emotions which most closely exemplify the cognition-emotion interface, are epistemic emotions. Epistemic emotions refer to emotions that are triggered by the knowledge-generating aspects of cognitive tasks (Pekrun & Stephens, 2011). Thus far, the studies that have tapped into epistemic emotions, have examined their relation to epistemic beliefs (Muis et al., 2015), problem-solving (Muis, Psaradellis, Lajoie, Di Leo, Chevrier, 2015) and reasoning (Blanchette, 2014). Also epistemic emotions have been subject to exploration regarding their antecedents and outcomes (D'Mello, Zehman, Pekrun & Graesser, 2012) during simulated collaborative learning situations. Yet, epistemic emotions is still an under-explored category of emotions (Muis et al., 2015) and further research is required to illuminate our understanding of the interplay between epistemic emotions, reasoning and learning. The current research aims to address this gap in the literature, by examining the interplay between epistemic understanding, epistemic emotions and argumentation.

Methods

Sample
40 fifth graders (11 year olds) participate in the present study. Participants are students from two classrooms from a public elementary school in Cyprus.

The SOCRATES web-based learning environment
The SOCRATES web-based learning environment that was developed by Iordanou and Constantinou (2015) is employed in the present study. The learning environment was designed by a group of researchers and teachers - two elementary school teachers and two high school Biology teachers. Researchers had the leading role in the development of the educational curriculum, while teachers contributed substantially to the development of the knowledge base − finding relevant data and adapting them to be appropriate for high school students.
The SOCRATES learning environment is hosted on the platform of Stochasmos (Kyza & Constantinou, 2007). Stochasmos offered two main environments. The first is the Inquiry Environment, where a knowledge base for the topic of climate change was developed. The knowledge base includes different types of information − short texts, graphs, tables and images (e.g., a graph of Earth's temperature over years).The second is the WorkSpace environment, which hosts the reflective templates "Finding Evidence", "Own argument" and "Other argument" where students were asked to construct evidence-based arguments and reflect on the arguments they produced while they were engaging in dialogic argumentation. Stochasmos offered students the opportunity to transfer information from the Inquiry Environment to the WorkSpace environment, and vice versa, using the "Data capture tool". The platform also incorporated a chat tool, which was used for conducting students' dialogic argumentation. For more details regarding the SOCRATES learning environment see Iordanou and Contstantinou (2015).

Procedure

Initial and final assessments

Students' argumentation skills were assessed at both initial and final assessments. Two socio-scientific topics, solar energy vs. natural gas (intervention topic) and genetically modified food (transfer topic), were used for assessing students' individual argument skills. Students' positions and supporting arguments regarding the two topics were assessed individually in writing, after a short passage introducing the scenario had been presented. Each scenario presented two opposing positions regarding the topic, solar energy vs. natural gas, and for or against consumption of genetically modified food. Students have been asked to indicate their position by choosing among three options: the two alternative positions of each topic and the option "Undecided". Then an individual essay assignment followed for each topic.

Participants' epistemic cognition was examined through individual interviews, based on the interviews employed by Pluta, Chinn and Duncan (2011). Participants' epistemic emotions while they were engaging in different activities in the intervention were examined through a questionnaire based on Epistemic Emotions Scale, developed by Muis, Psaradellis, Lajoie, Di Leo, and Chevrier (2015).

Intervention

The intervention took place over 13 sessions. Students had available a learning environment which had been developed for the purposes of the present study. The mission of students was to get prepared for a final showdown that would be conducted by the end of the intervention to inform students and their parents about alternative sources of producing electricity.

Finding Evidence

In the first sessions students were asked to review the information included in the learning environment and construct evidence-based arguments, with the help of the "Finding Evidence" reflection sheet. The purpose of preparing those arguments, they were told, was to get prepared for the series of discussions that would follow. The "Finding Evidence" reflection sheet asked students to state a claim and to provide evidence from the LE to support their claim. A separate reflection sheet was used for each argument they made. All the reflection sheets constructed were saved by the system in each student's account to be available for students to access them when they would engage in electronic discussions.

Argumentation

Then students engaged in a series of electronic dialogs with an opposing side pair. In each of these sessions participants discussed with a different opposing pair. Participants were asked to engage in these dialogs with the goal to persuade their interlocutors, who hold an opposing position, that their own position was right. After the completion of each dialog participants reflected on an electronic transcript of their dialog, with the help of two electronic reflection sheets the "Own Argument" and the "Other Argument". The reflection sheets are based on the reflection sheets that were used in Iordanou (2010) and Iordanou and Constantinou (2014; 2015) studies.

Showdown

The culminating point of the curriculum activities was a class level electronic debate between students holding opposing positions.

Results

The study is in progress. The results of the study will be presented at the conference.

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Environmental Learning Through the Lens of Affinity Spaces: Transforming Community Members Into a Community Force

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Abstract: In this paper we use affinity spaces as a lens to understand how adult community-based learning happens in an environmental education program. Participants take a series of classes and undertake guided experiential activities related to watershed issues and then carry out capstone projects in their own communities that address stormwater management issues. Within the context of the Watershed Stewards Academy, we aim to understand how participants bring diverse perspectives and experiences, interact with one another, and engage in environmental learning and action. Our analysis traces learners' development from becoming aware of the importance of stormwater management to the watershed's health to taking leadership roles in their communities. Our findings point to the potential of new face-to-face strategies and technology that can aid learners in interacting and learning together.

Keywords: informal learning, environmental education, adult learning, affinity spaces, technology

Introduction

Learning about the environment has become increasingly important for addressing society's most pressing issues of the 21st century—including energy consumption, climate change, and water pollution—particularly because many people are largely uninformed about the scientific processes underlying environmental phenomena and actions that could be taken to address problems. For example, Robelia & Murphy (2012) found that in a national survey, 59% of respondents could not accurately describe a watershed, and they did not know that various practices within watersheds contribute to water pollution or that preserving wetlands reduces runoff and thus improves water quality.

We draw upon affinity spaces as a lens to understand how adult learning happens within a mid-Atlantic Watershed Stewards Academy (WSA), one of a network of stewardship programs focused on training citizens to serve as community resources on local watershed issues and solutions. The WSA includes classes, experiential learning, and capstone projects that address some aspect of stormwater management and includes a community education component. We aim to understand how participants with diverse perspectives and experiences interact with one another as they engage in environmental learning and action through the WSA. Developing a nuanced perspective of how learning happens within this context informs our broader understanding of how to design and support adult community-based environmental learning through face-to-face strategies and technology as appropriate.

Aspects of environmental learning

Environmental studies researchers have pointed to three key aspects of environmental learning. First, and most obvious, is content knowledge, which includes understanding the scientific phenomena behind an environmental issue (e.g., the cycle of rainwater washing pollutants from parking lots, drains, and sidewalks into rivers, streams, and bays) (Robelia & Murphy, 2012; Walter, 2009) and what actions to take. Second, Clover (2002, 2013) advocates for learners to move beyond emphasizing content knowledge and individual action to develop critical reflection skills so that they can evaluate macro-level issues and policies that affect the environment. Ignoring the larger issues that form the core of local, state, national, and international policy decisions can have profoundly detrimental impacts. For example, Clover (2002) describes a neighborhood movement to recycle in which, unbeknownst to the community, the city was dumping its recycling out with the regular trash to cut down on costs, thus pointing out that individual actions alone may not be enough to create change. Clover (2002) calls this type of understanding "*concientización*". The third aspect of environmental learning involves expanding from individual actions to systemic community-wide endeavors that stem from a deep understanding of the impact of policy and infrastructure on the environment. These actions often require a collective effort by people from diverse backgrounds (Clover, 2013).

While these characterizations of different learning approaches provide useful overviews, they are often not explicit about how learning happens and how we might best promote it. For example, they do not focus on

community-driven learning among adults, the topic of this study. To fill these gaps, we turn to affinity spaces as a lens for gaining a deeper understanding of learning within the context of the WSA, and for exploring the kinds of scaffolding –human and technical – that might help the WSA and similar adult learning communities.

Affinity spaces: A lens for examining environmental learning among adults

Gee (2005) uses the term *affinity spaces* to describe locations in the real or virtual world in which people interact around a common passion or interest with others who have different expertise and who take on different roles, sharing their knowledge, tools, and technologies. Example studies have typically included gaming communities and enthusiast clubs (e.g., Star Wars online fan groups) – spaces that are usually informal learning contexts where interaction occurs virtually or in physical environments, and often both. These affinity spaces offer opportunities for community members to engage in science deeply connected to their interests and values, and they provide low-risk opportunities for them to explore potential roles they might take in science, especially when the science is directly relevant to their own lives (Clegg et al., 2014). Gee (2015) describes how affinity spaces consist of a *rich problem solving context* and *interest-driven sites.* This framework is particularly well-suited for understanding learning in the WSA in which *a rich problem-solving context* entails learning how to solve a watershed problem and culminates in a capstone project; the *interest-driven site* is the WSA program and the local community in which learning occurs. Gee advocates that the two should be studied as a unit because participants' experiences are integrally developed as they navigate both. During this development, there is often a rich interplay of diverse ideas as community members make suggestions influenced by their own experiences. We concur with this suggestion, which we believe applies to adult learners in the WSA context.

Gee proposes three types of diversity that may facilitate sustained learning experiences for participants. First, affinity spaces should bring together people with different orientations to, and expertise in, the domain of interest. Second, affinity spaces need to promote diverse modes of engagement among participants. Third, distinct roles and multiple ways of contributing support the need for diverse ways of learning. Therefore, in order to apply Gee's theory of affinity spaces to our AWS context we need to understand the ways participants interact within these spaces and how their roles come together to support learning. This understanding is important for informing how we might design learning environments and associated tools (e.g., technologies) to systematically support classes and community-driven environmental projects that facilitate adult learning.

Study context: Watershed Stewards Academy

The Watershed Stewards Academy (WSA) is a volunteer training program designed to equip individuals with the resources, tools, and knowledge to serve as leaders in their communities on watershed issues. Stewards participate in a 12-session course, and then have up to a year to develop and complete a capstone project in their own communities that has to do with stormwater management and community education. Upon course and project completion, they become Master Watershed Stewards. According to a 2014 survey, those who participate in WSAs in this mid-Atlantic state tend to be predominantly female (64% female; 36% male), white (78% white; 22% non-white), highly educated (89% reported at least a college degree), and older (mean age of 51.5 and median age of 53.5) (Fisher, Yagatich, & Galli, 2015). The WSA studied is working to increase diversity among participants by partnering with local faith-based organizations and expanding outreach efforts.

Methods

In a 4-month period between June and September 2015, we conducted 4 individual interviews and two focus groups with a total of 15 past and current WSA participants, who were at different stages in the WSA course. Some participants were beginning their classes, others were starting their capstone projects, and some had completed their projects. The first focus group was conducted as part of a WSA class with seven stewards; the second was a special session with four past WSA participants. Questions for the focus groups addressed motivation for joining the class, capstone projects, and the use of technology to accomplish their project goals. Additionally, two researchers observed the capstone project proposal presentations of a cohort of stewards at the end of their 12-week class and recorded field notes. One of the researchers was also a participant in the class.

Data analysis

Three researchers collaboratively developed a codebook consisting of 17 codes based on the conceptual framework and the concepts discussed in the interviews and reports of observations, paying special attention to participants' descriptions of aspects of the WSA program, such as the 12-week class experience, ideating capstone projects, collaborating on projects, and use of technology. Codes were also developed for tracing participants' learning experiences (i.e., learning developments) and instances of steward collaboration. Data was analyzed in a

deductive process and using the simultaneous coding system on Dedoose, a qualitative analysis software tool. Two researchers coded subsets of the focus groups and interviews using the codebook. Analytic memos were used throughout the coding process. Tables were applied to codes to illustrate overlapping ideas in order to capture the full learning experience and the development of participants' learning. In this way we could infer the learner's experience from the data (Miles et al., 2013). A third researcher then conducted a second coding pass across the data to inductively develop patterns within the codes for learning developments, steward collaboration, and challenges stewards faced.

Findings: How learning happens

Developing Awareness and Understanding in the 12-Week Class. The patterns we observed from the data suggest that during the 12 weeks of class, participants became aware of the impact of stormwater pollution on the environment. They also began to consider community and policy issues as they learned to assess stormwater management practices, toured green sites and interacted with their WSA facilitator and other stewards, which they began to take to their own homes, neighborhoods, and work places. For example, Ian[1] described doing site audits in the program: "*It was really low tech ... we went around to houses, and that really gave you a perspective of how little people think about water issues around their home*" (focus group 2). Another participant said: "*I didn't know that half of the water in our [religious facility] is not being treated before it hits the river. And I had no idea that we are dumping about 12 million gallons of water into the river every year*" (interview).

Fueling Passion with Capstone Project Work. These inquiries into their own contexts fueled participants' ideas for their capstone projects as many chose projects rooted in their own interests, neighborhoods, and professions. For example, Liz chose to focus her capstone project on the religious facility that she managed. As participants began to implement their projects, they reported common learning needs, e.g., to understand effective ways to manage stormwater (e.g., rain barrels, rain gardens), ways to build and create management systems (e.g., what types of plants to put in a rain garden) and how to handle problems that arise.

Becoming a Community Force. As participants carried out their projects, they reported taking on more leadership roles in their communities and changing how they viewed themselves and the local river. For example, Barbara reported that she began to educate her father about runoff principles and encouraged him to question his practices. Pattie discussed the importance of engaging in larger scale projects for increased impact: "*I think a really, really big benefit to the [WSA] program would be to connect with either the county planning boards or even the state planning boards*" (interview). Another steward suggested scaling up capstone project efforts through *"mega projects"* that integrated multiple capstone projects (focus group 2).

As stewards carried out their projects, they reported running into many challenges, including working with large communities, developing connections with the community, motivating community members to take continued action required for the upkeep of completed projects, dealing with changes in community leadership, and understanding the competing priorities of community members. Other kinds of challenges included scoping their capstone ideas into feasible projects, needing to invest significant time and energy to complete projects, obtaining funding for materials associated with their projects, and accessing appropriate technology for conducting site audits and recording other data. One interesting theme that emerged from our data was the stewards' dynamic interactions with each other. This theme may tell us more about creating "interest-driven sites" for supporting learners in this affinity space, such as by facilitating discussion of ways to address their challenges through leveraging their own social capital, culture, expertise, and past experiences.

Discussion, conclusions, and implications

Our analysis reveals stewards' progression from first developing awareness and understanding of stormwater issues in the 12 weeks of classes, to then becoming passionate about stormwater management as a result of their capstone projects, and (for some) ultimately becoming community leaders through their continued efforts. This progression suggests that community-driven environmental projects are a context in which learners can begin to develop *concientización* (Clover, 2002, 2013) in which they begin to progress from individual action and awareness to broader community action and leadership. Though some were able to make this leap, they expressed a desire for more support such as help with linking to additional learning resources and opportunities. These findings support Gee's call for problem solving within interest-driven sites (Gee, 2015).

Considering the challenges and interactions stewards faced from an affinity spaces perspective suggests that stewards of community-driven environmental projected may benefit from more diverse "interest-driven sites," specifically online spaces, social media, and other types of technology (Lammers et al., 2012; Gee, 2015). Of the 120 past and current WSA participants we invited to meet with us, only 11 were able to attend the face-to-face events. Online forums may thus offer additional opportunities for collaboration and engagement that fit within the contexts of their busy lives. Such interest-driven sites are spaces in which learners can articulate and

organize their knowledge, interact around a problem-solving context to develop new possibilities for solving problems, mentor and learn from one another, and specialize in specific aspects of the context (Gee, 2015). Our analysis suggests that interest-driven sites for community-driven environmental projects need to support stewards at two levels: first, for *awareness and understanding* of stormwater management principles and practices; and second, for *communication and interaction*, particularly during their capstone projects as they engage with their communities. Integrating face-to-face and online support for these conversations would enable diverse modes of participating over time as called for by affinity spaces researchers (Lammers, et al., 2012). The kinds of tools that are needed in interest-driven sites include project management, communications, and mapping tools, which will most likely be technological in nature.

Drawing on an affinity spaces perspective, we conclude that a framework that extends beyond traditional teaching perspectives is needed in this context. A framework that emphasizes prompting, supporting, and sustaining learner-driven environmental experiences would extend those already offered (e.g., by Clover, 2002, 2013; Walter, 2009), by highlighting the importance of helping learners find the right learning experiences and resources (e.g., funding sources, lectures, hands-on experiences) at opportune times to support and empower them in their own local and larger-scale contexts. This approach must balance the structure needed to promote learning with freedom for learners to direct their own learning so that they develop their own personal value for the environmental contexts in which they are working. We advocate for a framework that takes a variety of perspectives and that helps learners to link to new learning opportunities and to take on leadership roles in their own local and global environmental contexts. More work is needed to develop such a framework and to understand how interest-driven sites, especially those that provide rich technology support, can be integrated with face-to-face experiences in this and similar contexts to support learning, empowerment, and leadership in community-driven environmental projects.

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Students' Responses to Curricular Activities as Indicator of Coherence in Project-Based Science

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Abstract: Project-based learning seeks to engage students through sustained investigation of real-world problems or design challenges. Weekly mini-surveys were administered to students during an 8-week project-based learning unit to understand students' perceptions of alignment of lessons to the overall challenge, their affective responses to lessons, and how these varied across lesson types and teachers. Results from a multilevel model revealed significant teacher level variance; no differences across lesson types were found.

Keywords: project-based learning, science, practical measurement, coherence, student affect

Introduction

Project-based learning aims to support the development of deep understanding of subject matter by engaging students in sustained investigation of problems (Blumenfeld, Soloway, Marx, Guzdial, & Palincsar, 1991; Edelson, 2001). Organizing projects around specific questions or design challenges is intended to make projects cohere from students' point of view (Krajcik & Mamlok-Naaman, 2006). Challenges also provide motivation for students to develop knowledge components related to disciplinary core ideas (Schwartz & Bransford, 1998).

Successful projects require students' sustained effort, since answering driving questions and solving design challenges unfolds typically over many lessons and weeks (Blumenfeld et al., 1991). Projects with sufficient novelty and authenticity are hypothesized to capture and sustain student interest in subject matter learning, by helping students connect disciplinary ideas to real-world phenomena (Blumenfeld et al., 1991; Polman, 2012).

However, developers cannot presume that a particular driving question will sustain students' attention. Student motivation depends on their perceptions of the value of the tasks, and the alignment of the specific tasks with the overall phenomenon (Pitts, 2006). Moreover, engagement may vary across lessons of a unit, in ways that are attributable to both lesson characteristics and individual differences of students (Pitt, 2006). When youth view tasks as contributing toward answering a driving question or design challenge, they may perceive tasks as more valuable. Different lesson structures may also influence these perceptions.

We know that variation in teaching practices explains differences in student outcomes in project-based science instruction (e.g., Fogleman, McNeill, & Krajcik, 2011; Harris, Phillips, & Penuel, 2012). We expect, then, that student experiences of project-based learning vary not only by lesson but also by teacher. In classrooms where teachers' enactments of lessons emphasize connections between tasks and driving questions or challenges, students are likely to experience tasks as valuable because they see those connections themselves. To date, research has not examined teacher-level differences in student experiences of project-based learning.

Methods

In this study within a larger design-based implementation research (Penuel, Fishman, Cheng, & Sabelli, 2011) project, we gathered data from students using an electronic "mini-survey" about their experiences of individual lessons in a project-based unit on ecosystems. Our primary purposes were (1) to develop implementation evidence related to the experienced coherence of the unit and (2) to contribute to knowledge related to student engagement in project-based learning.

The focal unit is an 8-week project-based unit organized around a design challenge: "Select a species of tree to plant in your schoolyard that will maximize biodiversity and ecosystem services." The unit is intended to develop understanding of disciplinary core ideas in the life sciences identified in *A Framework for K-12 Science Education* (National Research Council, 2012). We intended our mini-survey to serve as a "practical measure" (Yeager, Bryk, Muhich, Hausman, & Morales, 2013) that could be implemented by teachers on a regular basis to inform the iterative refinement of individual lessons in the unit.

Sample

Data from the study come from 592 students of 11 teachers from eight schools in a large urban school district in the United States West region. The majority of students in the district are Hispanic and 69% participate in the free/reduced lunch program. Our data sample consists of 1,223 surveys submitted by participating students from August 25 through October 28, 2015.

Student mini-survey

Teachers administered the student mini-survey on a weekly basis. The analysis presented here focuses on responses to two items presented in the survey: (1) "We learned about something today that connects to the challenge." (Yes, No, Not sure), and (2) "Today in science class, I felt..." (Excited, Bored, Like a Scientist). We did not seek to construct scales from these measures, in accordance with practical measurement's focus on a few indicators judged to be of central concern for implementation (Bryk, Gomez, Grunow, & LeMahieu, 2015).

The first item addresses students' perceptions of the alignment of the day's tasks with the overall design question. The second addresses their understanding of the purpose of the day's lesson. The third addresses their affective response. This item was adapted from an earlier study of students' responses to an elementary-level project-based unit in science (Morozov et al., 2014), and we used it to allow for comparisons across projects. We conjectured that there would be positive associations among perceptions of alignment, understanding of the purpose for the day's lesson, and feelings of excitement and identification with science.

Approach to analysis

We fit multilevel models to the data using the software HLM 7.0, which were appropriate to the nested nature of our data. Models each had three levels: observation or occasion, student, and teacher. Each teacher had multiple students, and each student had between 1 and 8 different observations where they completed surveys. In one model, ratings of connectedness to the challenge over time were outcomes we sought to model in order to understand variation associated with both teacher and lesson type. Lessons were grouped into two types: those emphasizing *discursive* practices (e.g., argumentation) and those emphasizing *investigation* practices (e.g., planning and conducting an investigation). This nesting structured necessitated a three level model. The three level model of our outcomes include time-dependent student predictors in level one (e.g., affective measures and whether or not students rated the lesson as hands-on or discursive). In a second set of models, students' emotional responses to lessons (excited versus bored) were outcomes, and we modeled variation associated with teacher and with individual students' ratings of connectedness to the challenge over time.

Findings

Results from each of the three-level hierarchical linear model we fit revealed significant teacher level variance; no differences across lesson types were found. Specifically, the unconditional model of outcome "connected to challenge" produced significant variance at the teacher level. Of the total variance in the model, 30.5% was at the teacher level. Table 1 shows the results of a model that explores the degree to which lesson type accounts for variation in student ratings that a given lesson was connected to the overall challenge. Neither lesson type was significantly associated with type of lesson, though the probability of an investigation-focused lesson being rated as connected to the challenge was higher than for discursive-focused lessons (43% versus 32%). A significant percent of variance remained at the teacher level, when these predictors were included in the model.

Table 1: Model of lesson connected to the challenge with type of challenge as predictors.

Outcome - Model	Predictor	Coefficient in Log Odds (se)	Coefficient in Probability	% Variance at Teacher Level
Connected to Challenge *Unconditional Model*				30.5%
Connected to Challenge *Type of Lesson*	Investigation-focused	-0.28 (0.33)	0.43	34.7%
	Discursive-focused	-0.37 (0.20)	0.32	

A second model focused on predicting whether students reported feeling excited during the lesson. An unconditional model fit to the data revealed a significant percent of variance at the teacher level (13.7%). Once

student ratings of whether the lesson was connected to the challenge were included as a predictor in the model, the percentage of teacher variance changed to 40.1%. Ratings of connectedness to the challenge were significantly associated with students' reports of being excited during the class. Seventy percent of lessons that students reported being connected to the challenge were ones where they also reported being excited.

Table 2: Model of *excited* emotion with lesson connected to the challenge.

Outcome - Model	Predictor	Coefficient in log odds (se)	Coefficient in probability	% of Variance at the Teacher Level
Excited				13.7%
Excited *Connected to challenge*	Connected to challenge	0.84* (0.37)	0.70	40.1%

A third model focused on predicting whether students reported being bored during the lesson. An unconditional model fit to the data revealed a significant percent of variance at the teacher level (29.9%). Once student ratings of whether the lesson was connected to the challenge were included as a predictor in the model, the percentage of teacher variance jumped to 40.6%. Ratings of connectedness to the challenge were significantly associated with students' reports of being excited during the class. Thirty-one percent of lessons that students reported being connected to the challenge were ones where they also reported being bored.

Table 3: Model of *bored* emotion with lesson connected to the challenge.

Outcome - Model	Predictor	Coefficient in log odds (se)	Coefficient in probability	% of Variance at the Teacher Level
Bored				29.9%
Bored *Connected to challenge*	Connected to challenge	-0.79 (0.48)	0.31	40.6%

Conclusions and implications

These findings indicate that teacher-level differences influence student experiences of project-based learning. Teacher-level differences influenced the degree to which students perceived their learning tasks to be connected to the unit's design challenge and the tasks' overall usefulness outside of class. In turn, teachers' abilities to help students connect tasks and lessons to the unit challenge may influence students' affective responses, such as feeling excited during project-based learning tasks. We found no differences across lesson types, which contrasts with the findings reported by Pitt (2006).

These findings have multiple implications for practice and research. First, these findings underscore that teachers need professional development that specifically targets project-based learning instructional practices. Helping students make connections between daily tasks and lessons, and larger unit goals, may be critical for maintaining student interest and engagement during the sustained, in depth investigations typical of science projects. Furthermore, curriculum materials could be enhanced with instructional routines, for instance during lesson opening and closing, that support students in making relevant connections.

Second, our experiences suggest that there is great utility in these relatively simple mini-surveys for gathering rapid feedback from learners as part of a design-based research process. For instance, we have compared student self-report of their affective responses across successive design and implementation cycles to gauge the degree to which changes in unit tasks and materials were "improving" the unit with respect to student engagement. Asking students to assess the degree to which a daily task or lesson is related to a larger unit challenge also offers a new "student-centered" way of looking at and measuring the coherence of instruction. This approach is a potential complement to other assessments of curricular coherence, which focus on analyzing the connectedness of ideas as represented in instructional materials (Kesidou & Roseman, 2002). By asking students directly, we are tapping into the coherence of the "experienced curriculum" rather than the "formal" curriculum (Gehrke, Knapp, & Sirotnik, 1992), thus shifting the measure to better reflect the actual student experience. In future analysis, we will compare these student self-report data with classroom observations conducted as part of this larger research program to develop additional evidence related to validity of this approach to studying coherence as experienced by students.

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A Qualitative Exploration of Self- and Socially Shared Regulation in Online Collaborative Learning

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Abstract: This qualitative study explored how groups with high or low self-regulation regulated their collaborative behaviors. We used purposeful sampling to select two groups of students in an online course with the highest and lowest mean self-regulation scores, based on survey data. We inductively analyzed online discussion posts and identified three themes that described the groups' processes for externalizing and internalizing understanding: level of engagement with content, approach to seeking and providing help, and openness to disagreement and problem-solving. The group with the highest mean self-regulation scores elaborated upon course concepts, helped one another understand and apply ideas, and integrated viewpoints to carry out course activities. The group with the lowest scores wrote about surface-level features, exchanged help in a brief and depersonalized manner, and moved quickly to consensus without evaluating alternative perspectives. These patterns illustrated marked differences in the development of socially shared regulation.

Keywords: self-regulation; socially shared regulation; online learning; collaborative learning

Introduction

The extant research on self-regulated learning often emphasizes examining relationships between self-regulation and students' engagement, achievement, and affective characteristics. For group learning contexts, scholars (e.g., Hadwin & Oshige, 2011) proposed the concept of socially shared regulation, "processes by which multiple others regulate their collective activity" (p. 258). Researchers have studied this concept to explain how groups of individuals, as multiple self-regulating agents, socially regulate each other's learning in social learning contexts (e.g., Hadwin, Oshige, Gress, & Winne, 2010; Järvenoja & Järvelä, 2009). Some studies have shown evidence that socially shared regulation may lead to motivation and learning (e.g. Järvelä, Järvenoja, & Veermans, 2008; Lajoie & Lu, 2012). DiDonato (2013) explored how group regulation influenced students' self-regulated learning in a middle school environment. She found qualitative evidence from students' interactions that members of a group could regulate others' planning, monitoring, and evaluating of learning.

It remains unclear, however, whether and how self-regulated individuals shape group-level socially shared regulation in collaborative learning; reciprocally, little is known about whether and how group-level socially shared regulation influences self-regulated individuals. Socially shared regulation of learning in small group online collaborative learning often is mediated through students' engagement in asynchronous online discussions (Xie, Yu, & Bradshaw, 2014). Students post and respond to messages to externalize their knowledge and understanding. They read to internalize the group understanding to build their own knowledge (Xie, 2013). These group dynamics may then further shape individual self-regulated learning. We conceptualize this interactive process as socially shared regulation. The purpose of this study was to explore this process by examining how self-regulation of learning led to the development of socially shared regulation in collaborative learning in an online learning environment.

Methods

Student sample and data sources

The qualitative case study involved undergraduates taking an elective online study-strategies course at a large public university in the Midwest United States in autumn 2013. Students worked in small groups of 6-7 students over a two-month period in 5 collaborative online discussions. Each discussion occurred in conjunction with a related assignment; topics included note-taking, reading, charts/visual organizers, outlining, and changing habits. Halfway through the course, and prior to their participation in the online discussions, students completed a confidential online self-report survey. The survey was based on the Motivated Strategies for Learning Questionnaire (Pintrich, Smith, Garcia, & McKeachie, 1991) and asked students about various aspects of self-

regulated learning using a seven-point Likert-type response scale. We calculated the individual self-regulation scores to identify the groups with the best and worst average self-regulation scores. Consistent with case study methodology, we used purposeful sampling (Patton, 2002) to identify groups with the highest and lowest mean, respectively ($M_{\text{Group A}} = 4.98$, $M_{\text{GroupB}} = 3.68$). These groups' discussion posts ($n_{\text{GroupA}} = 120$, $n_{\text{GroupB}} = 93$) became the focus of the inductive qualitative analysis.

Analysis

Discussion posts from the course's learning management system were exported and analyzed by the first two authors. In our first round of analysis, we employed open coding to annotate salient interactions and identify topics to explore further (Corbin & Strauss, 2014). We examined all discussion posts a second time, which yielded 20 codes that reflected students' participation and engagement. We reviewed one another's annotations and reflective memos to reach shared understanding of the coding scheme, then met to reduce the codes into overarching themes that characterized differences in socially shared regulation between the two groups.

Findings

High self-regulation led to high socially shared regulation as group members externalized (i.e., articulated) and internalized (e.g., reflected on or synthesized) their understanding. Specifically, three key differences emerged in the posts written by students in Groups A (high self-regulation) and B (low self-regulation): (1) level of engagement with content, (2) approach to seeking and providing peer help, and (3) openness to disagreement and problem-solving.

The theme *level of engagement* reflected how students explained their thinking and understanding. Interactions among students in Group A were characterized by reflection and elaboration upon course concepts. In contrast, students in Group B reused examples and descriptions from the textbook or restated content from peers' posts without further analysis.

The second theme of *seeking and providing peer help* reflected how students reached out to and assisted one another to clarify understanding and address personal challenges. Students in Group A demonstrated effective help seeking by providing specific explanations of their current processes and requesting assistance for particular challenges. In contrast, students in Group B tended to pose general questions and receive vague, repetitive responses.

The third theme of *openness to conflict and problem-solving* reflected how group members worked as a team. Group A's members expressed a willingness to disagree and explore multiple perspectives on a topic. In contrast, Group B's members leaned toward consensus rather than challenging another's ideas. When it came to working together, Group A's members exchanged ideas to reach a productive solution. In contrast, Group B did not have a clear sense of direction, and individuals took a passive role in asking others to tell them what to do.

Conclusions and implications

This study illustrates key differences in the quality and depth of learning in online collaborative group discussions, while supporting the importance of shared regulation in this environment. Across the themes identified in this study, common elements characterized the posts of students who had high self-regulation. These characteristics included identifying tasks and needs, elaborating upon ideas, engaging in reflection, synthesizing and evaluating concepts, and inviting alternative perspectives. Students with high self-regulation personalized and clearly articulated their own examples and ways of understanding, which led to their group member's understanding and application. In contrast, the more limited contributions and engagement of students low in self-regulation did not appear to promote either individual or group learning. Our study extended the understanding of the dynamic interplay between self- and socially shared regulation to online collaborative learning contexts, where students' interactions with the content and one another often determine how well they achieve course outcomes (Didonato, 2013).

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Exploring the Composition Process of Peer Feedback

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Abstract: This paper presents a study that explores the composition process of peer feedback. It adopts an interactional framework for feedback that takes into account feedback sender's and recipient's factors. Participants were pre-service mathematics teachers ($N = 47$) enrolled in a course about feedback and assessment. Quantitative content analysis was used to analyze students' reflections after being involved in a peer feedback provision activity on a geometry construction task. Students' reflections illustrated that the composition process is not purely cognitive, and can also involve self-reflection and self-evaluation activities as well as peer-related activities. Some examples of self- and peer-related activities during peer feedback composition are reported, followed by a discussion of implications for using peer feedback as a learning activity.

Keywords: Peer feedback, assessment for learning, feedback training, mathematics

Introduction

The role of students in classrooms has changed in the last decades with a strong emphasis on empowering students and actively involving them in assessment activities. Peer- and self-assessment are now common practices in which students evaluate quantitatively or qualitatively the correctness and the quality of their peer's or their own performance. The purposes of involving students in such assessment activities can vary, but they are normally meant to improve students' performance, evaluation and analytical skills, or both (Topping, 2003). Peer feedback (PF), which is regarded as the qualitative component of peer-assessment, is used as an instructional tool in many fields. Since the value of feedback is in the information that can be used to improve learning, most of the PF research focuses either on the quality of the feedback message or its application. Only recently some studies started to explore the learning gains of students who provide PF. In an experimental study Cho and MacArthur (2011) showed that, compared to the control group, the quality of students' written scientific reports improved significantly after involving them in providing PF. They hypothesized that while providing PF, students might engage in problem solving processes through which they reflect on and improve their own learning. While their study illustrated the learning gains resulting from providing PF, it purely focused on the outcomes of the act of providing PF. To date, little is known about the process resulting in the provided PF, i.e. the composition process of PF, and the cognitive, social and affective processes involved in that process. A survey by Nicol, Thomson and Breslin (2014) highlighted some cognitive processes that could be part of the PF composition activity, such as critical evaluation, reflection on one's own work, and comparing one's own work with peers' work. However, composing PF is not just about reflection on one's own work as students are expected to produce a feedback message to be delivered to their peers. It can be hypothesized, therefore, that multiple self-related and peer-related cognitive, metacognitive and affective processes take place simultaneously during the composition of a PF message. Further, involving students in PF provision cannot guarantee that they will automatically engage in self-reflection and problem solving activities. For instance, PF can be cognitively demanding, especially for students who have insufficient knowledge about the topic at hand. These students might spend most of the PF activity trying to understand the peer's solution. This is supported by Van Zundert, Sluijsmans, Könings and Van Merriënboer (2012) who showed that providing PF, when combined with insufficient domain-knowledge, was detrimental to the PF provider's performance; especially when the task was complex.

Many prominent feedback frameworks focus on the type, function and/or purpose of feedback (e.g., Kluger & DeNisi, 1996; Hattie & Timplerley, 2007), partly because most of the feedback research focuses on teacher's feedback which is used to help students improve their learning. However, when it comes to PF different interrelated processes and moderators can shape students' learning. Strijbos and Müller (2014) proposed a conceptual framework of feedback which incorporates the composition, provision, reception and processing of feedback as interactive processes taking into account the context and the personal and interpersonal factors of the feedback provider and the receiver. Particularly interesting is the composition process, which is mostly ignored by PF research or regarded identical to the provided PF message. According to Strijbos and Müller (2014) the

composition process is influenced by the context (e.g., learning environment, the task), the providers' personal factors (e.g., empathy) and their personal representations of the feedback recipient (e.g., vulnerability to negative feedback). Although the feedback message can act as a good indicator of what the feedback provider knows or does not know, it does not provide any information about how the provider went about creating that feedback message. Moreover, instructional guidance during PF training tends to focus on the PF message (e.g., marking rubrics) rather than scaffolding students' learning from the PF activity (e.g., self-reflection support). In sum, these observations signify a need to explore the cognitive, metacognitive and affective processes students engage in during the composition of PF.

Research questions

This paper addresses the following research questions: (1) Which processes (cognitive, metacognitive, and affective) are reported by students while composing PF on a geometry construction task?, and (2) To what extent does the PF composition process reflect a self-orientation versus a peer-orientation?

Method

Participants and design

The participants were forty-seven pre-service mathematics teachers enrolled for a teaching degree for middle school. They had a mean age of 22.7 years ($SD = 2.57$, age range: 19-29) and seventy percent were female. We conducted an intervention study as a part of a mathematics teacher education course about feedback and assessment. Participation in the PF activities was mandatory as part of course requirements, but inclusion in the study was voluntary (informed consent).

Material

Student reflections were collected during the intervention study in which pre-service mathematics teachers were trained to provide PF (based on Hattie and Timperley's (2007) model) on a geometry construction task. Students received an evaluation rubric for geometry construction, a worked example, and feedback prompts. After PF provision, the students were asked to reflect on PF provision and the PF composition process guided by the following prompts (this paper only focuses on prompts 2 and 3):

(1) What did you learn about geometry construction from providing feedback?

(2) What did you consider/ focus on while composing feedback on the solution of your peer?

(3) Please write down other things you thought about while giving feedback.

Analysis

Quantitative content analysis was used to analyze the reflections, because it is a systematic technique for text analysis. A coding system is the main instrument for analysis and the interpretation of data is theory guided (Mayring, 2014). Before coding the reflections, they were segmented based on Strijbos, Martens, Prins and Jochems' (2006) procedure using the smallest meaningful segment as the unit of analysis. Two independent coders segmented 7 out of 47 reflections (15%) reaching an agreement level of 81% lower bound and 88% upper bound. One of the coders segmented the remaining reflections. A coding scheme was developed using the segmented reflections and guided by the research questions. Two independent coders coded 15% of the reflections reaching an acceptable level of inter-rater reliability on the main categories (Krippendorff's $\alpha = .78$). One of the coders coded the remaining reflections. A total of 222 segments from 47 students were analyzed.

Findings

Peer feedback composition processes

Three main categories emerged from the data namely cognitive, metacognitive and affective, with specific sub-categories for each main category (see Table 1). The cognitive category involves all statements about actions or thoughts about the PF message (e.g., structure and accuracy) and the composition of PF (e.g., evaluation of solution) at the cognitive level. The metacognitive category is about monitoring and regulation thoughts or actions about the provider's own learning or PF. The affective category refers to attempts to motivate or preserve the feelings of the peer by avoiding negative comments or emphasizing positive aspects. Most of students' reflections were at the cognitive level (76%), followed by the metacognitive (15%) and the affective (9%) level. At the cognitive level students focused mostly on the structure and accuracy of the PF message (32.5%) followed by the

evaluation of the peer's solution (23.5%), which is not surprising given the instructional support (i.e., feedback prompts, evaluation rubric and worked example). At the metacognitive level, students focused mostly on monitoring and evaluating their PF message (53%), self-reflection (31.3%) and PF provision self-efficacy (15.6%).

Table 1: Categories of the PF composition processes with definitions and examples

Main category	Sub-category	Definition	Examples
Cognitive	Structure and accuracy	Related to the structure and clarity of the PF message	"I tried to write my feedback in a clear and understandable way"
	Procedural and conditional	Related to the process of composing the PF message	"How to give feedback when the answer is correct?"
	Evaluation of solution	Related to error detection and evaluation of peer performance	"Identifying mistakes"
	Self-reference evaluation	Evaluating the solution relative to one's own solution or thoughts	"I compared the solution to how I would do it"
	Comprehensibility of solution	Related to clarity of and trying to understand the peer solution	"Can I understand all the described steps?"
	Inferring peer's knowledge	Inferring what the peer knows or was thinking about	"Trying to see if the student had a basic level of knowledge"
	Higher cognitive processing	Thinking of alternative solutions, and going beyond correctness of the peer solution	"I tried to find another way to solve the task"
	Improvement purpose	To help peer improve their solution	"Make peer's solution work with changes"
	Questioning solution	Making peers think about their solution	"I asked questions to see if he knew what he was doing"
	Being critical	Related to being critical and objective when providing PF	"How to be objective"
Metacognitive	Self-reflection	Referring to one's own ability to solve the task	"Would I solve it the same way?"
	Self-efficacy	Related to perceived difficulty of providing PF	"Difficult to find mistakes"
	Monitoring and self-evaluation	Monitoring of the PF provision process	"Is my feedback as good that the same or another task can be solved without any problems?"
Affective	Motivating and praising	Related to motivating the peer, avoiding negativity or emphasizing correct parts of the peer solution.	"Encouraging by emphasizing the correct"

Me and my peer: Two overarching themes

Within the cognitive, metacognitive and affective main categories, we identified self-related (me) and peer-related (my peer) aspects. Examples of the peer-related actions/thoughts at the subcategory level include: comprehensibility of solution (cognitive), inferring peer's knowledge (cognitive) and motivating and praising (affective). Examples of the sender's self-related actions/thoughts were: self-reference evaluation (cognitive), higher cognitive processing (cognitive), being critical (cognitive), reflection on one's own ability to solve the task or to provide PF (metacognitive) and monitoring the PF composition process (metacognitive). Figure 1 shows the proportions of self-related (me) and peer-related (my peer) statements at the main category level (i.e., cognitive, metacognitive and affective). Peer-related statements are very prominent in the cognitive and affective categories. This might be because students are concerned with how to compose feedback to their peer, how it should appear to their peer and how to evaluate the solution by their peer.
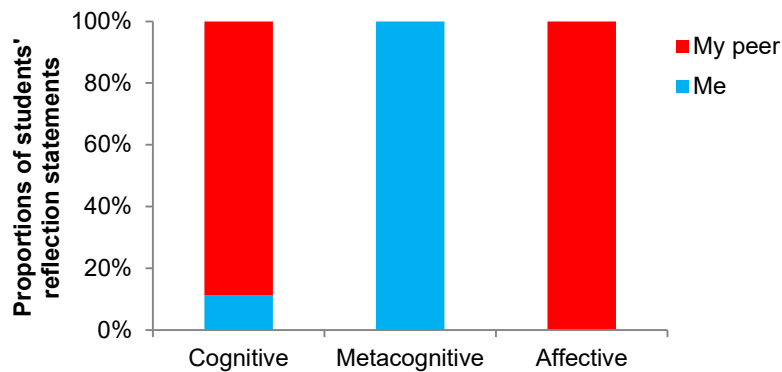
Figure 1. Cognitive, metacognitive and affective self- (me) and peer-related (my peer) statements.

Conclusions and implications

Our results show that the PF composition process involves multiple self- and peer related activities which are not necessarily evident in the PF message. They also show that students can engage in critical evaluation and self-reflection during PF composition as suggested by Nicol et al. (2014). Nonetheless, students appear to focus more on the structure of the PF message (at least in this study). One of the limitations of this study is that students' self-reports were used to explore a complex process like the PF composition. Therefore, the reported activities are by no means regarded as the only experienced activities. Rather, they provide a glimpse of possible cognitive, metacognitive and affective activities of the PF composition process. The findings of this study have several implications for educators who use PF as a learning activity. First, we should pay attention to the PF training and support materials we provide to the students, which are based mostly on the PF message. We cannot expect learning to take place through self-reflection during PF composition if we do not train and scaffold such self-reflection. Second, as suggested by Strijbos and Müller's (2014) interactional framework, representations of peers' characteristics or expected reactions (i.e., affective) seem to be activated during the PF composition activity. One direction for future research is to investigate the effects of affective aspects of a PF message on the learning of the PF sender and recipient. Additionally, the PF sender could receive instructional support about how to balance one's representation of the peer recipient, regulating personal learning, and the impact of such support on the composition of a meaningful and useful PF message.

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Let Your Data Tell a Story: Disciplinary Expert Feedback Locates Engaging in Argumentation in a Holistic System of Practices

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Abstract: Trends in science education promote engagement in authentic knowledge in practice to tackle personally consequential science problems. To better understand what authentic practice looks like in a classroom, we examine interactions between scientists and students on a social media platform during two pilot enactments of a project-based curriculum focusing on the ecological impacts of climate change. Scientists provided feedback to students on infographics meant to communicate to an audience about climate change. We conceptualize the feedback and student work as boundary objects co-created by students and scientists, and analyze the structure and content of the scientists' feedback. We found that in feedback on a particular practice scientists encouraged students to participate *systemically* in practices instead of isolating one practice. Engaging with scientists around established scientific texts and data sets provided students with a platform for developing expertise in other important scientific practices during argument construction.

Introduction

The *Framework for K-12 Science Education* and the Next Generation Science Standards were the first science education policy documents in the United States to position scientific practice on equal footing with science content knowledge through a three dimensional science learning model that partnered specific student performance expectations with related disciplinary core ideas, practices, and crosscutting concepts (NRC, 2012; NGSS Lead States, 2013). This practice turn in science education shifts focus away from knowledge accumulation to its application in context, with the intention of making visible to learners the performative aspects of research. In response to Next Generation curriculum structures, designed curricula should be oriented towards developing students' *disciplinary practice knowledge* in addition to content knowledge, and central to our understanding of this knowledge base is the inherent social, holistic, and systemic nature of science knowledge construction. However, more research is needed to understand what disciplinary practice knowledge looks like in diverse contexts, and how to equitably support implementation at scale. This study investigated how a curriculum design that partnered high school biology students with related disciplinary experts helped cultivate disciplinary practice knowledge through engagement in a holistic system of science-related practices during the shared construction of an evidence-based classroom artifact, an infographic, intended to communicate the research and implications of climate change on ecosystems.

We leverage social practice theory, specifically the lens of legitimate peripheral participation (Lave & Wenger, 1991) to understand how students became engaged in a system of disciplinary practices as they constructed evidence-based arguments to communicate the ecological impacts of climate change in partnership with disciplinary experts. Through the process of legitimate peripheral participation, individuals learn with others and develop expertise by observing and increasingly participating on the edge of a community of practice as they develop the shared discourse and practices of a given community (Lave & Wenger, 1991; Engle & Conant, 2002).

The curriculum design in this study leveraged everyday technologies to situate high school biology student on the boundary of related disciplinary communities of practice by partnering them with scientists as they developed a scientific artifact, the infographic. We analyze the infographic as a boundary object, which Star & Griesemer (1989) define as "objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them yet robust enough to maintain a common identity across sites." Here, the infographic helped scientists and students navigate disciplinary discourse around climate change argumentation, evidence, and communication and situated students on the boundary of a related community of practice in which experts modeled the rich system of disciplinary practice involved in crafting and communicating scientific arguments from professional data and evidence. Here, the infographic and the shared data set as boundary objects (Akkerman & Bakker, 2011; Star & Griesemer, 1989; Wenger, 1999) that mediated and scaffolded scientific discourse between learners and disciplinary experts.

Methods

This study draws on data from a larger curriculum development project to create year-long courses in Life Sciences and English Language Arts. Design principles included giving students opportunities to engage in

authentic scientific problems, to utilize scientific practices such as performing fieldwork, analyzing and using computer models, and writing scientific texts. The curriculum used a social media platform that connected students to each other, and also to disciplinary experts. Both courses were created using a design-based research approach in which individual modules were designed, implemented, and revised based on findings. This study examines the student-scientist interactions that occurred in the first two six-week pilot enactments of a module on the Ecological Impacts of Climate Change in the Life Science course. The first pilot implementation (11 students) occurred from March - April, 2011 at Shale High School, an alternative school in a rural town outside of a major city. We conducted our second pilot study of the climate change curriculum from Oct-Dec 2011 in two 9th grade classrooms (40 students) at Quartz High School, an alternative school in an upper-middle class suburb of a major city. In the climate change enactments, 14 disciplinary experts reviewed student work, interacted with students via Skype, and visited the classroom.

Analysis targeted the interactions between scientists and students that occurred during the two pilot enactments, including written feedback scientists gave students on their infographic drafts (5 from Pilot 1, 17 from Pilot 2, provided on the social media platform) and scientists' questions and feedback on student's final presentations (Pilot 2 only, in person). Documents containing student work and scientist feedback and transcripts of scientist-student interactions were analyzed using the mixed-methods software Dedoose. Assertions were generated based on emergent themes and we searched the data corpus for disconfirming evidence (Erickson, 1986).

Findings

In the feedback from the scientists, the construction of successful arguments and communication artifacts was deeply entwined with other scientific practices and scientists modeled ways in which they would approach a problem or improve the argument or communication. While scientists reference all practices included in the NGSS, below we discuss in detail the practices of asking questions, designing and conducting investigations, constructing explanations and communicating information.

1. Wondering, speculating and asking questions. Scientists' open-ended questions allowed them to engage with student work by using the evidence students provided as a starting point for further investigation. In doing so, they revealed their own problem-solving processes. For example, in one instance a scientist responds to a student group's work on sea level rise and the monk seal by considering other climate parameters that could be affecting the monk seal:

> I wonder if rainfall plays a major role in the Monk seal life . . . for instance – do they only go
> to the breading[sic] ground during the dry season or the wet season? If you can figure that out
> – then you might be able to argue that a change in climate can lead to a change in rain patterns
> and that might have some sort of impact on the seal life cycle?

In this excerpt, the scientist is pursuing a line of thought that would supplement and fortify the students' initial argument about the impact of climate change on monk seals by providing a second line of evidence about impacts. She "wonders" if changes in rainfall could potentially have consequences for the monk seal's mating. This is an open-ended, speculative question in that it is not a question that the scientist knows the answer to *a priori*. Instead, she models what her own practice would be in theorizing about relevant variables and interactions, offering a hypothesis that she encourages the students to "figure out" if it is supported or not by available evidence. If it is supported, the scientist suggests that having multiple lines of evidence would improve the argument. As opposed to a standard view of scientists as sources of information, through wondering or speculating questions, scientists did not supply any new "facts" or evidence, instead demonstrating how they would approach thinking through possible relevant interactions and evaluating whether or not they supported a particular argument. This example demonstrates the connection between two key practices in the Next Generation Science Standards: asking scientific questions and developing arguments from evidence. Asking these questions was a necessary step in developing rigorous, convincing arguments because it is how one obtains evidence and considers alternate or additional contingencies.

In many instances, scientists asked questions that were open-ended, but that it can be reasonably assumed the scientist already knew the answer to, either in full or in part. These were coded as "probing questions" and were the most common question type. These kinds of questions also modeled scientific questioning practice, and supported argumentation as through these kinds of questions, scientists processes of building arguments by highlighting the need for more evidence, more explanation or clearer logic.

2. Scientific explanation in argumentation. The infographic assignment required students to both explain the scientific evidence and use it in an argument about how climate change might affect ecosystems. In feedback to students, scientists critiqued the explanations for completeness and correctness, offered supplementary information that supported student explanations, and made suggestions about how to improve coherence between the text and graphics for explanations.

Scientists' comments included supplemental factual information that expanded student explanations. For example, one student group proposed that the Canada Lynx and snowshoe hare would not be able to shift their range north because they already live at high latitudes. The scientist giving feedback added in a comment: "In addition, the area north of the lynx's range is mostly tundra and lynx are found mostly in forest." This statement provides new information that both supports the student's argument but also builds out their explanation of constraints on range shifts. By providing this just-in-time content, scientists provided input aimed to help students create more thorough and conceptually accurate explanations.

Scientists also pointed out places that students could improve their argument by incorporating more scientific explanations. For example, in one instance a scientist encouraged a student to investigate and explain the impacts on plant growth in more detail:

> You might want to help the reader make the connection between climate change and plant growth by explaining some ways climate change might affect plants – what are some things plants need that might be changing?

In this instance, the scientist specifically gears the student to consider what would be helpful for "the reader"—thus, this scientist is concerned with explanations needed to communicate the student's argument. Scientists also noted when the text and graphics didn't align, specifically when explanations of figures and graphs were missing. Scientists' feedback centered on the importance of not only including data but explaining it well in order to clearly communicate to an outside audience.

3. Designing and carrying out investigations. In the unit, students designed and carried out an investigation into the effect of changing climate parameters (e.g. temperature, water) on Wisconsin Fast Plants, a fast-growing *brassica* species and conducted fieldwork on phenology through a citizen science effort. While students reported that they enjoyed both activities, students rarely utilized the data they collected themselves through these investigations on their infographic. Rather than using their own data, they instead pulled from established data sets, such as the climate model results discussed above. This deviates from a common inquiry model in science classrooms in which students carry out their own investigations through physical manipulation. Instead of using their own results, students engaged in an investigation more similar to data mining, in which individuals query existing data to answer questions. This is an authentic practice in climate science, as much work is conducted as analysis of large, shared data. The feedback scientists provided on this kind of investigation overlapped with feedback on data analysis, use and interpretation, and there were no instances in which scientists gave specific feedback on how to carry out empirical investigations or collect data.

4. Obtaining and communicating information. The infographic assignment provided students with the opportunity to employ multiple modalities in construction of their argument. This is congruent with common scientific communication practices in which both visual elements (e.g. graphs, tables, pictures) and text are used. One scientist noted the authenticity of the infographic product as similar to scientific poster presentations. She used the idea of a story to frame the construction of a poster (or infographic) and positioned the student's work as part of a real scientific practice and also provides insight into how a scientist might think about constructing a poster that tells a "story". A "story" provides a different connotation than an "argument" or "infographic." The scientist suggests adding visual elements that would also help tell the story: "You could even draw an arrow between the facts and analysis or put a box around them so that it's very clear that they're connected." This feedback highlights the role that design has on its success as a communication tool.

Many scientists made comments about the appropriateness of visual elements, the placement and arrangement of the elements, and suggested new visual elements to include to improve either the ability of the infographic to communicate to a particular audience, or the validity of the argument. For example, scientists evaluated whether or not visual elements actually provided support for the argument. Referencing the inclusion of a map of Florida sea level rise in an infographic about polar bears, one scientist asked: "Are changes in Florida relevant to polar bears?" suggesting that the visual element might not be the most appropriate. In some cases, scientists made comments about visual elements they thought would be appealing or helpful to readers from a communication standpoint.

Conclusions and implications

Disciplinary practice knowledge is a broad and diverse arrangement of knowledge and practices that take many forms in professional, community and learning settings. The findings from our study suggest that scientists' views and communication of their own practices align with the integrative three dimensionality of the NGSS. By modeling their own questioning and learning processes, scientists encouraged students to craft and interrogate their arguments by employing a suite of related practices. For the scientists, providing feedback on students' arguments and communication necessarily involved critique on the interrelated web of scientific knowledge construction practices. Multiple practices can and did occur in the same act-- developing an explanation was a part of argument construction, and using models required data analysis. The boundaries between the practices are more fluid than the rigid list of eight in the NGSS might suggest.

The practice of modeling through literary inscription (Latour & Woolgar, 1986) was also intimately tied to argumentation and communication of data, and professional data sets served as useful boundary objects that enabled students and experts to mutually construct climate change related arguments across classroom and professional boundaries. During the climate change unit, students generated their own climate-change related data through classroom phenology experiments, in addition to data mining publicly available professional climate change data sets. However, in this case the student-generated data was not robust enough to serve as a boundary object across contexts as students rarely leveraged their own data to support or communicate evidence for the ecological impacts of climate change on their infographics. Although the scientists were aware of the student-generated data, they also never requested or added to student-generated data pieces. In contrast, publicly available professional data sets proved to be robust boundary objects that mediated disciplinary discourse between students and scientists, and were easily leveraged to communicate the ecological impacts of climate change to diverse audiences. The adaptability of these professional data sets across contexts enabled the scientists to effectively model disciplinary ways of knowing for students.

Boundary objects, such as common data sets, are commonly used in professional science context to connect related communities of practice, to provide diverse lenses and expertise around existing knowledge bases and to engage related practitioners in sense-making practices around bounded pieces of evidence. Our research suggests that social networking technologies and disciplinary data sets can effectively position students as legitimate peripheral participants on the boundaries of related disciplinary communities of practice. As Wenger (1999) noted, innovative learning can happen on the boundaries of these communities in ways that enable students to maintain their existing identities regarding climate change perspective, while robust boundary objects can allow them to work in partnership with disciplinary experts to construct evidence-based stories of the ecological impacts of climate change that engage students in holistic learning as described by NGSS.

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Acknowledgments

A Design Approach to Understanding the Activity of Learners in Interdisciplinary Settings: Environment and Diversity

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Abstract: The aim of this paper is to describe the design approach developed to analyze the design and consequent activity of learners engaged in an undergraduate environmental science course. The course was taught using the EMBeRS method that emphasizes generation of external representations of mental models to build shared understanding of socio-environmental systems (Pennington et al., 2015). The design approach adopted combined expertise in (1) design research (from Sandoval, 2014) and (2) design for learning (from Carvalho & Goodyear, 2014). Taking a systems view of the design, activity, and learning outcomes, this paper describes the linkages between these and extracts the design conjectures of the instructor and the theoretical conjectures implicit in the EMBeRS approach. In collaboration with the instructor, the use of this approach: identified disconnects between design and theoretical conjectures; linked these disconnects to specific design considerations so that; recommendations for areas of redesign and parallel research were made.

Keywords: design, interdisciplinary problem solving, collaboration, environmental science

Introduction and background

In environmental science, finding ways to engage in productive interdisciplinary collaborative research is essential to finding solutions to real world problems, such as climate change. A synthesis approach to research focuses on the integration of perspectives to create a shared model of a given system, as a negotiated boundary object, to represent and mediate conversations about the phenomenon in study. In synthesis research, interdisciplinary teams come together to refine existing data, ideas, theories or methods, from many sources, and across multiple fields (NCEAS, 2014; Kemp & Boynton, 2011). A synthesis approach is necessary when an individual perspective cannot answer questions, but the integration of knowledge and perspectives across disciplines into a shared model has been identified as one of the key challenges to the success of this method of research (Roy et al., 2013). In 2013, a number of programs were funded to investigate the design of undergraduate and postgraduate programs around socio-environmental synthesis skills. This paper focuses on one of these projects: Employing Model-Based Reasoning in Socio-Environmental Synthesis (EMBeRS). The EMBeRS approach (Pennington et al., 2015) combines model-based reasoning with an emphasis on the creation of, and conversation around, boundary negotiating objects (Lee, 2007; Pennington 2010). Model-based reasoning is a feature of scientific thinking (e.g. Nersessian 2002) that science educators have been striving to support in science learners (e.g. Jacobson & Wilensky, 2006; Lehrer and Shauble, 2006; 2000; Raghavan & Glaser, 1995). The EMBeRS project elaborates on this approach for use in interdisciplinary contexts. Specifically, the approach allows disciplinary experts to share aspects of their internal mental models by collaborating to generate and refine external representations of complex systems. During this process, it is expected that experts will uncover and reconcile discrepancies in their understandings of a system and over time develop a more comprehensive synthetic understanding of a complex problem (a shared problem model).

In parallel to developing the EMBeRS approach (for a full description see Pennington et al., 2015), members of the project team also developed an approach to design for, and analyze, the resultant learning. Our aim was to describe the organization of collaborative interdisciplinary learning environments in terms of the design, the activity of learners and instructors, and the outcomes of learning so that we could articulate and test conjectures about learning to do synthesis research. In this paper we present an example of an analysis of a lesson from an undergraduate environmental science course designed using the EMBeRS approach.

Methods

We take a systems approach to analyzing learning that allows us to propose conjectures about the mechanisms underlying commonly reported measures of effectiveness, such as learning gains. Understanding the relationships between the components in a system of learning helps us to better predict whether a successful design is repeatable or transferable. We can ask whether the observed success is linked mechanistically to intentionally designed

aspects of the program, or whether it emerged from as yet unconsidered features of the program or participants (learners or instructors). We draw on recent work in design for learning (Carvalho & Goodyear, 2014) and design-based research (Sandoval, 2014) to map learning systems in a way that centralizes the activity of the learner – where the mechanisms of learning unfold. Drawing on the work of Carvalho & Goodyear (2014) we map learning environments by accounting for (1) the designed elements, including tasks (epistemic), role and rules of interactions (social) and digital and physical learning environment and tools (set); (2) learner activity (observable learner behavior); and (3) the learning outcomes (measurable changes over time). We will then illustrate how to analyze such systems adapting conjecture mapping (Sandoval, 2014) to draw out and evaluate the (1) design conjectures that link designed elements of a learning environment to the desired activity of learners (conjectures about how the design will be enacted); and (2) theoretical conjectures that link the activity taking place in a learning environment with anticipated learning outcomes (conjectures about how people learn).

This paper focuses on an exercise designed as part of an undergraduate, first year seminar course called *Everybody's Environment*. The course included 16 students with an expressed interest in a range of majors. We describe the design of the EMBeRS exercise, as well as the observations made of learner activity, particularly in relation to assessing the ability of students to engage in the core objectives of the EMBeRS approach (broadening of individual perspectives mediated by boundary negotiating objects in a collaborative setting).

Findings

The students engaged in a sequence of activities to explore different understandings and conceptualizations of the term *environment*. The instructor intended to use this exercise to prepare students to adopt the EMBeRS approach to address a more complex problem later in the course. As outlined in the EMBeRS approach (Pennington et al., 2015), students were expected to have the opportunity to a) identify their own view (perspective) of *environment*; b) listen to and understand other students' perspectives; c) share their own and others' perspectives (written and oral); d) collaboratively construct a representation of their shared understanding; and e) apply this to another problem. Students engaged in a sequence of tasks over three days:

Task 1 required students to identify one resource that represented their view on *environment* and provide a reason for their choice. The responses were submitted online, and brought to class. In Task 2 students were placed in dyads to describe their resource, changing partners several times over 20 minutes, until all students had interacted with each other. Students individually reflected on a guiding question about what they had learned about others' representations of the environment, and these were presented to the class. Students were then divided into groups of three based on proximity and given ten minutes to identify commonalities and differences in their resources, followed by another individual written reflection about their learning. Finally, the whole class discussed the individual reflections, which were recorded on the board by the instructor. Task 3 was completed asynchronously. Students were asked as individuals to identify one resource (visual, symbolic) that represented their small group's view on environment and provide a written description as well as a reason for choosing the resource, submitted online and face-to-face in the following class. In Task 4 the resource and explanation from Task 3 were shared in class with the same groups of three as the first day, and the students were asked to write a guided reflection as individuals. In the same groups of three, students were asked to generate a mind map of shared understandings and perspectives of the environment, which were photographed and shared with the class. One of the groups utilized computer software to generate their concept map, while the remainder drew their maps on notebook paper.

The design of the exercise is outlined in Figure 1 below. The *epistemic* elements of the design were a series of subtasks that elicited external representations as well as explanations and reflections of perspectives about the definition of *the environment*. Repetition around the key skills (creation of artefacts, discussion, reflection) was used to train students in the cyclical nature of the EMBeRS approach. The *set* design supported the creation and sharing of artefacts, explanations, and reflections, and allowed these to be accessible by the instructor and learners as needed during the subtasks. The *social* design included a series of individual, dyad, small group, and whole class discussions, aligned carefully with the epistemic elements. Beyond this, however, the social activity of the learners was unscripted; there was no scaffolding of the collaboration in terms of roles in the groups or rules to follow.

The observable learner activity was characterized in terms of the same three constructs: epistemic, social and set. The key epistemic aspect of learner activity was identifiable changes in perspectives about the environment, most obviously identified in the written reflections and descriptions of the artefacts. It was anticipated that learners would use the tools available, physical and digital, to aid them in communicating their perspective to the group and the instructor. It was also anticipated that the social interactions, and the rules and roles that emerged during the structured collaboration would help learners to shift perspectives, as per the

EMBeRS approach. The projected learning outcomes revolved around preparing learners with the skills required to adopt this approach later in the semester, including collaboration, artifact creation, and writing.
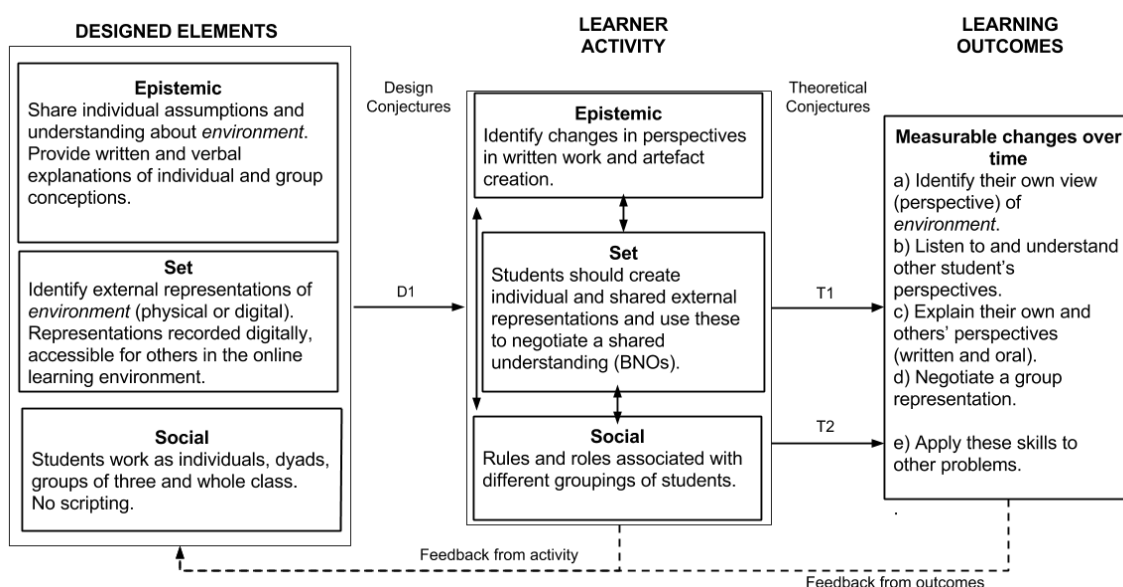
Figure 1: Representation of the key design elements considered in *Everybody's Environment.*

Discussion and conclusion

Our analysis allows us to explicitly draw out the conjectures embedded in the design of this lesson. The primary design conjecture (D1) was that the design elements would work together to generate discourse and activity in which students would share and negotiate their perspectives. It was assumed that the construction and refinement of representations would mediate this process, allowing students to record and reference their ideas. The instructor also assumed that a range of understandings of *environment* would exist among the students. The design purposefully encouraged a range of modalities to present these understandings, including written and verbal, interpersonal, intrapersonal, as well as visual and spatial. Most of the resources identified by the learners were digital (including photos and music), however some were physical resources (including a book and a terrarium). There were two theoretical conjectures identified. The first (T1) linked this intended activity (iterative, collaborative externalization and negotiation of perspectives) to shifts in individual students' perspectives about *environment*. The second (T2) was that participation in this exercise would prepare learners to participate in further model-based reasoning in groups later in the semester.

With these conjectures articulated we were able to identify evidence in the observed learning activity and learning outcomes. The instructor observed various levels of sharing, description, inquiry and collaboration, and noted discrepancies between the collaboration in real-time, and written explanations submitted. What was not clear without recordings of the collaborative tasks was the role that the different social groups had in the generation of artefacts or shifts in perspectives. Further investigation is needed before support can be given to the design conjecture. A shift in perspectives was observed by the instructor in the written and oral descriptions (related to T1), most noticeably in recognizing that not all students identified nature as environment, but identified themselves or their neighborhood or some other physical space as environment. Students did articulate their own and others' perspectives, and participated in generating shared representations. Further analysis needs to be done of the artefacts produced to understand how the interaction of different types of learner activity supported this. To test T2, the instructor applied the same design to the discussion of another term (diversity), rather than an environmental case study. Student comments included feedback that the exercise was not academic enough, as it provided no grounding in the literature in terms of defining or conceptualizing the concept of *environment*.

In the following, we consider the feedback from the three aspects of the activity of learners, and the learning outcomes. The *epistemic* design seems to have been successful, at least in terms of anecdotal reporting of participation in the task. Further research could investigate the reflections and artefacts for evidence of perspective change, particularly to understand how this interacts with the other design elements. The design of the *set* was complex with online, digital and physical artefacts created and shared by individuals and in groups. Future research should address the interaction between this heterogeneous learning environment and the role of

the boundary negotiating objects in the shared understanding of the key term. The design of the *social* groupings was complicated (individual, dyads, small groups and whole class), further investigation is needed of the rules and roles that emerge in further iterations in order to ensure that timely support is given to groups as necessary, or to reconsider the complexity of the groupings. The feedback from students implies that they lacked motivation to apply these skills to the negotiation of a second key term. This may be linked to the epistemic design. In synthesis research, experts come together around a pressing environmental problem that they want to solve. In the classroom task, students were engaged in defining a term (an initial step towards solving a problem) without the context of the bigger problem that this would help them to solve. Changing the focus of the exercise to an authentic environmental issue, around which differences in worldviews or mental models exist, warrants further investigation.

By combining the approaches that foreground both design-based research and design for learning, the key considerations of the instructor as well as learning sciences researchers can be included, and in so doing, provide a more informed design of a complex task. Given the roll out of the EMBeRS approach in multiple institutions (Pennington et al., 2015), a systematic way of assessing the variations of the design as well as the resulting activity and learning outcomes support their comparison across learning environments. As the results are further refined, design guidelines can be developed to support the successful implementation of EMBeRS.

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Acknowledgments

Teamwork in the Balance: Exploratory Findings of Teamwork Competency Patterns in Effective Learning Teams

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Abstract: Teamwork is an important life skill and competency for 21st century learners. It also contributes to effective learning teams. In this exploratory study, we examine the different levels of team effectiveness and describe the varying patterns of teamwork competency dimensions from students' online problem-solving chatlogs. We employed two types of measures for a holistic understanding of team effectiveness, namely, task performance scores and learners' perception of how effective they are as a team. Teams were categorized into four levels of team effectiveness based on the measures. A content analysis of teamwork competency dimensions was also performed. Our findings revealed the need for balance in teamwork competency behaviors for effective learning teams. Insights from the findings could lead to design principles for interventions to nurture teamwork competency in our 21st century learners.

Keywords: teamwork, 21st century skills, effective learning teams, chatlog, CSCL

Introduction

Teamwork is one of the important 21st century competencies for learners of this day, yet learning how to become more competent at it can be challenging. Amongst the difficulties is that the concept of teamwork is not easily identified or measured in the classroom. Nevertheless, past research has acknowledged transportable measures of teamwork. However, these have tended to focus on learner perspectives rather than their interactions. There has been limited research that identifies teamwork competency measures through the interaction and dialogue of teams. In line with CSCL research that focuses on the interactions paradigm (Dillenbourg, Baker, Blaye et al., 1996), we examine the chatlog of learning teams for teamwork competency dimensions. Moreover, synchronous chat is considered a useful medium as it allows teams to spend more time in deep reasoning and distributes participation (Sins, Savelsbergh, van Joolingen et al., 2011). As part of a larger study, a six dimensional teamwork competency model for learning teams was developed from past literature and pilot studies (Koh, Hong, & Seah, 2014) namely: coordination (COD) - organizing team activities to complete a task on time; mutual performance monitoring (MPM) - tracking the performance of team members; team decision making (TDM) - integrating information, selecting the best solution, and evaluating the consequences in a team; constructive conflict (CSC) - dealing with differences in interpretation between team members through discussion and clarification; team emotional support (TES) - supporting team members emotionally and psychologically; and, team commitment (TCM) - identifying with and being involved in team goals.

Teamwork is complex and research is still ongoing on the conditions and processes of effective teams (Näykki, Järvelä, Kirschner et al., 2014). Team effectiveness can be measured through performance scores and perception surveys. In this current study, we employed both types of measures for a holistic understanding of team effectiveness, i.e., task performance scores and learners' perception of how effective they are as a team. Teams can be categorized into different levels of team effectiveness. Several papers have compared effective teams with ineffective ones in order to characterize and identify behaviors of effective teams (Soller, 2001). Similarly, this exploratory study will examine different levels of team effectiveness and describe the varying patterns of teamwork competency. We ask, what are the teamwork competency patterns of various team effectiveness levels? Identifying these patterns can help teams to become more aware of their processes and subsequently adjust their team behaviors and learn to become more effective teams.

Method

Activity and dataset

An online collaborative problem-solving activity was created as one of the programs in the Project Work curriculum. The participants were 14 year-old, Secondary Two students in a Singapore Secondary School. In randomized teams of 3 or 4 in a class, students used synchronous group chat to solve the tasks. Prior to the problem-solving task, students were given an icebreaker task to help them get to know their team members and familiarize them with the chat system. For the problem-solving task, students had to discuss online and collaboratively find a solution to a dilemma scenario of a factory run by a student's father which was polluting the environment and affecting the health of the elderly in a nearby hospice. Students were given about 45 minutes in class to solve the task in teams, after which they responded to a survey.

All the students in the Secondary Two level who had the Project Work subject were invited to participate in the study. This resulted in 76 teams. For this analysis, we focus on 34 teams as content analysis for these teams have been completed; the coding for remaining teams is still in progress. These 34 teams have a total of 9778 chat lines ranging from 71 to 487 lines per team and an average of 287.6 lines per team.

Team effectiveness measures

Team effectiveness was measured through task performance scores in the problem-solving task and self-reports of team members. The last answer given by a team in the chatlog was extracted as the final answer, which was used to measure task performance score. This final answer was marked by a teacher based on a rubric which evaluated the solution's understanding of the task requirement and coverage extent.

For the self-report measure, three items from the team effectiveness scale (Van den Bossche, Gijselaers, Segers et al., 2006) were used. Individuals rated this on a 5-point Likert scale with 5 being strongly agree. This was then aggregated at the team level, and averaged within the team.

As this is an exploratory study and our data was slightly skewed, we performed a series of median-splits to classify teams into effective and less effective teams. This resulted in four levels of team effectiveness:

- Level 1: Low task performance score and low self-report team effectiveness items
- Level 2: Low task performance score and high self-report team effectiveness items
- Level 3: High task performance score and low self-report team effectiveness items
- Level 4: High task performance score and high self-report team effectiveness items

We emphasized the performance score over the self-report as this is a slightly more objective measure. Table 1 provides the descriptive statistics of team effective measures and team effectiveness levels.

Table 1: Team effectiveness descriptive statistics and level means

Team Effectiveness Measures	Mean (n=34)	SD (n=34)	Min (n=34)	Max (n=34)	Level 1 (n=12)	Level 2 (n=7)	Level 3 (n=11)	Level 4 (n=4)
Task performance score	1.59	0.82	1.00	4.00	1.00	1.00	2.55	2.00
I am satisfied with the performance of our team (EFF1 team average)	4.02	0.55	2.50	5.00	3.81	4.50	3.77	4.48
I would want to work with this team in the future (EFF2 team average)	3.68	0.68	2.25	5.00	3.52	4.29	3.23	4.35
As a team, we have learned a lot (EFF3 team average)	3.76	0.61	2.50	4.75	3.56	4.35	3.40	4.35

Teamwork competency coding scheme

The coding scheme is illustrated in Table 2 along with subcategories and examples. This coding scheme was theoretically informed as well as surfaced from the data. Each chat line was coded for presence or absence of each of the 6 dimensions; each line could be coded for multiple dimensions. Two researchers performed the content analysis; they coded 9 teams together and split up the other teams between them. Disagreements were discussed and agreed upon to create the final coding for the team. Cohen's kappa ranged from .714 to .964 while Krippendorff's alpha was .713 to .964 for the last 3 teams suggesting adequate levels of intercoder reliability. The coded dimensions were aggregated per team then averaged by team size as teams had different numbers of members. Table 3 reports the mean coded dimensions per team member.

Table 2: Teamwork competency coding scheme examples

Teamwork Dimension	Examples
Coordination (COD)	
Organize activities to complete task on time	"faster, only 10 minutes more"
Ask team members who is in the team	"Who else?" "Jane is in this team"
Coordinate logistics of task	"Type the answer"
Mutual Performance Monitoring (MPM)	
Give clarifying feedback to help in the team's performance	"Check this Wikipedia link"
Ask team members to contribute to the task	"John, what's your solution?"
Steer conversation back to task	"Shut up please"
Team Decision Making (TDM)	
Give ideas related to the task	"Move the factory"
Ask any task-related question	"Can the elders move?"
Exchange information about the task problem	"The source of the pollution..."

Constructive Conflict (CSC)	
Explain and give reason for disagreement	"Because its expensive and not easy"
Add on to ideas (Elaborate on ideas)	"Also, the fishes still die"
Propose different ideas	"How about we move the elders"
Team Emotional Support (TES)	
Greet and introduce oneself	"Hello, How are you"
Express positive emotions and emoticons	" Good ☺"
Appreciate team member (Give credit)	"John's answer is good"
Team Commitment (TCM)	
Express confidence in own team's ability	"We can do it"
Show togetherness through 'We' language	"We need one final answer"
Hold own team in higher regard compared to other teams	"Our team is better than Jane's"

Findings and discussion

Using descriptive statistics to examine the teamwork competency dimensions of the four team effectiveness levels, we found some interesting patterns. Table 4 reports the averages of teams and Figure 1, the bar chart.

Table 3: Coded teamwork dimensions descriptive statistics

Dimensions per member in team	Mean	SD	Min	Max
COD	10.17	5.04	2.25	18.67
MPM	5.06	2.82	.67	11.00
TDM	16.25	10.97	2.50	43.50
CSC	15.49	10.80	2.00	43.00
TES	11.74	4.44	4.00	20.33
TCM	4.31	3.08	.50	12.75

Table 4: Coded teamwork dimensions averages of Team Effectiveness Levels

Team Effectiveness Level	1	2	3	4
COD mean	10.38	9.01	9.92	12.25
MPM mean	4.93	5.02	4.99	5.71
TDM mean	18.86	12.70	16.45	14.08
CSC mean	17.69	12.23	15.92	13.35
TES mean	12.68	11.56	10.94	11.46
TCM mean	4.90	3.65	4.11	4.23
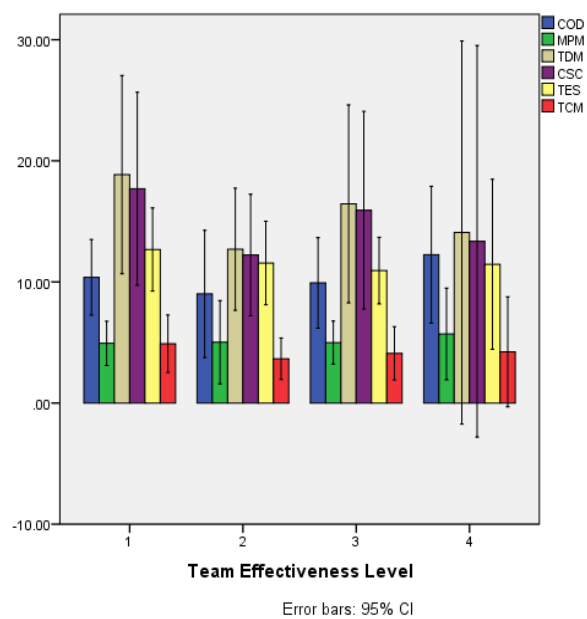
Figure 1. Bar chart of teamwork dimensions team averages of the four team effectiveness levels.

The level 4 category represents the most effective teams. This level had the highest MPM and COD means amongst the different team levels. Team chatlogs showed that team members engaged in behaviors like time keeping and steering each other back to task. They assigned tasks to members so that everyone played a part in solving the problem. This could suggest that MPM and COD are important aspects in effective teams. Also, for COD, TCM, CSC and TES, the amounts were quite similar per team member. This could suggest that a balance in the teamwork competency dimensions amounts characterize effective teams.

Level 3 teams did well in task performance but were not perceived as well by team members. Unsurprisingly, they had low levels of TES. The TES averages were the lowest compared to the other team effectiveness levels. An examination of the chatlogs revealed that in some teams, members had slightly different answers but one member of the team decided on the final answer and the other members acquiesced to the answer without showing strong support. COD was also relatively low and there was a wide gap between COD and TDM suggesting that while task ideas and elaboration were contributed, the team did not do much to coordinate the answer or want to complete the task on time.

Level 2 teams had low performance scores but high self-perceptions of team effectiveness. TES was the second highest among the four levels. While there were good amounts of TES, this level of teams had the lowest TCM, COD, TDM and CSC. The low TDM and CSC amounts indicate thin argumentation about the task which relates to the low performance scores. As for low TCM, this suggests learners were not that committed to the team's outcome. There seems to be close TDM, CSC and TES amounts, however as compared to level 4 teams, this pattern is missing a similar amount of COD. This further suggests that it is not just a few dimensions, but that more (or all) of the dimensions have to be present in balanced amounts for effective learning teams.

Level 1 teams were the least effective teams. Among all the levels, they had the lowest MPM amounts. MPM reduces free-riders as members check on each other. This suggests the importance of MPM to help improve team effectiveness. This level also had the highest TDM and CSC suggesting that there were many ideas and disagreements. Interestingly, this level had the highest TCM. The chatlogs revealed that students used "we" language in their task discussion frequently suggesting that they were committed to the task but at the same time had disagreements with their team members. There is a very wide disparity between COD and TDM too, suggesting that they could not coordinate their final answer well. Although TES is the highest among all the team levels, TES is relatively less compared to TDM and CSC, suggesting more disharmony than support.

These team effectiveness patterns point to the importance of the different dimensions of the teamwork competency measure. We argue that it is necessary for the dimensions to be present in similar amounts. In other words, effective teams require a balance of the different teamwork competency dimensions. This corroborates findings by Soller (2001) who found that the effective team had a balance of all the active learning, conversation and creative conflict skills compared to the ineffective team which was unbalanced and was missing a skill category. The balance of teamwork competency dimensions could also be related to socio-emotional balance found to be important for effective learning teams (Näykki et al., 2014).

Conclusion

Teamwork competency is a key lifelong learning skill and this study goes towards shedding light on effective teamwork behaviors. We note that our analysis is mostly based on descriptive statistics. We have performed a correlation analysis but no significant correlations were found. This is possibly because of the small sample size. Work is ongoing to content analyze more teams for further inferential analysis. Other work will also look into the relationship between the two team effectiveness measures. Nevertheless, this nascent finding of the need for balance in teamwork competency behaviors could lead to design principles for interventions to nurture teamwork competency for our 21st century learners. Although teamwork is complex, we are hopeful that new efforts can help enhance the clarity and power of teamwork.

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Problems With Different Interests of Learners in an Informal CSCL Setting

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Abstract: Interest drives engagement in learning and supports learners' spontaneous participation in CSCL settings. However, few studies have investigated how interest development is supported or hindered during learning activities. This microethnographic study explores how a learner's interest decreased during collaborative design activities in a summer camp for elementary-level students. The analysis shows that problems surrounding learners' different interests and facilitators' directed intervention could hinder interest development.

Keywords: Interest-driven learning, design thinking, informal environments, CSCL

Introduction

Recent scholars have emphasized the need to support interest-driven learning in learning environments (Evans, Won, & Drape, 2014), however, few studies have empirically considered the role of interest. Thus, conducting microanalysis, to see how interest is supported, decreased, or driving learning, may provide particular benefits for researchers in Computer-Supported Collaborative Learning. In collaborative learning settings, different individuals having their own potential interests interact with each other. This means there exists the possibility of a variety of interests interconnected to learners' experiences and the likelihood that not all of these interests would be supported. This begs the question, what happens during collaboration when different interests converge or diverge? In this paper, we conduct microanalyses of children (grades 3-6) working on a collaborative design project in a summer camp. We examine what happens when different interests are articulated and how the differences influence collaborative activity and interest development.

Conceptual framework

Interests in informal settings

Interest has been defined as a state of positive feelings attracting people's attention and cognitive engagement to particular tasks or objects (Ainley, 2006). Interest-driven learning, where learners' own interests can empower learning process, has a potential to be self-sustained, thus it is important to support and incorporate learners' interests into educational activities (Barron, 2006).

Informal settings, having plentiful resources, spontaneous participation, and active interactions among learners and environments, can afford learning based on interest and enjoyment (Lemke, Lecusay, Cole, & Michalchik, 2014). To realize interest-driven learning, recent studies have applied different activities, such as design activities, in informal settings (e.g., Evans et al., 2014). In collaborative learning environments, however, each learner may have different interests; but how different interests are supported or whether they contribute to a shared learning task is not certain. Few studies have investigated how differing interests impact collaborative interactions and collaborative learning: specifically how they are synthesized and used by the group. Therefore, it is necessary to conduct in-depth analyses on how learners' different interests influence collaborative learning tasks and vice versa.

Affective as well as cognitive consideration in CSCL

Interest is an affective state resulting from interaction with a physical or cognitive object (Ainley, 2006). You can help students develop interest by triggering opportunities for positive affect with external stimulus from learning environments or by designing learning tasks to match with learners' existing interests (Ainley, 2006; Hidi & Renninger, 2006). Thus, interest can be newly emerged or extended from existing interest. Either way, the important part in interest-driven learning is to support the continuous interest of learners so they can spontaneously engage with learning tasks. This is especially important in CSCL settings where multiple people can impact learning experiences and create opportunities or obstacles for the development of shared interest. When individual interests are ignored by other learners, it could present the potential for negative affect, as people react emotionally to such behaviors or reflect negatively about the collaborative experience (Ortony, Norman, & Revelle, 2005).

Many studies in CSCL have investigated how collaborative learning activities involve learners' cognitive development and interaction (i.e., Borge, Ong, & Rose, 2015), but affective aspects of learning cannot be detached from cognitive enhancement. Particularly, collaboration always involves social interaction between individuals, which naturally come along with emotional exchange. The affective aspect, getting a sense of pleasure from a collaborative experience, is one important motivational factor in collaborative learning (Jones & Issroff, 2005). Thus, when it comes to learning in CSCL environments, both cognitive and affective aspects should be equally considered. From this perspective, we explore learners' different interests during collaborative design projects by considering both affective and cognitive aspects. Accordingly, our research question is: What problems emerge when learners' differing interests intersect during collaborative activity, and how do these episodes impact collaborative design activities?

Methods

This qualitative study uses a microethnographic approach (Spradely, 1980), by exploring learners' interactions including talks and behaviors, to see what patterns within those exchanges influenced learners' interests.

Setting and participants

Our summer camp program was a multi-iterative daily one-hour club, held for four weeks at an elementary charter school in Pennsylvania. The primary aim was to introduce young learners to collaborative design activities in order to help develop higher-order thinking processes associated with design. As a part of design-based research, activities in our program underlined interest-driven learning (Barron, 2006); provided diverse resources (e.g., paper and pencils, Legos, laptops, tablet PCs) to use; supported learners engage in design projects based on design thinking process (Dym, Agogino, Eris, Frey, & Feifer, 2005). During the second iteration, in summer 2015, among 10 students enrolled, only eight students attended regularly. They were divided into two teams. This study focuses on Team 2, whose members included, Carlos (age 8), Mary (age 8), Emma (age 9), Hadwin (age 10). We selected this team because unlike Team 1, Team 2 expressed distinctly different interests and included members who all spoke English fluently.

Early video analyses indicated that children expressed their existing interests in early sessions and Lego challenges produced rich, interactive discussion data. As such this study focuses on the first Lego challenge, held during the first week of the camp (4 sessions). Two adult facilitators guided children to participate in the activities and one researcher stayed to observe the camp. The learners carried out a design challenge described in video resources developed for the camp (see Figure 1). The challenge was to design a garden for Lego Fred, a virtual client. This challenge involved questioning what Fred's needs were, planning different designs based on Fred's needs, creating designs with Legos, and testing the designs by comparing final product to a client profile and checking to see how well students met client needs.

Figure 1. Screen shots of video resources and design challenges developed for the camp

Data collection and analysis

Data sources included student generated artifacts and video data. The artifacts included learners' drawings, about their own expertise and final reviews about what they liked among the activities and resources provided. Team 2's interactions were recorded with a video camera and audio recorder, resulting in 3 hours of video/audio data. Three coders reviewed the video data for the purpose of identifying episodes where learners' interests were expressed. Coders had to justify or argue against selections using evidence based on common indicators of interest, such as expression of pleasure, focused attention and engagement, and committed talk, as defined by Ainley (2006). Coders then made agreements on where interests were expressed. These episodes, including ones that followed, show increased or decreased indicators of interest, and they serve as the main sources of data for this study. The analysis focuses on Carlos' decreasing interests in the collaborative project during the activities.

Findings: Problems around different interests among learners

The video data showed how the strength of learners' existing interests could pose problems during collaborative design activities. For example, Carlos had experienced the first iteration of this program and returned to the camp for the summer. He showed high interest in future science or new scientific materials, such as 'carbon nanotube', as he continued to talk about new materials and strongly asserted to use them in their design. Meanwhile, such scientific materials were not familiar or interesting to other teammates. The team, to which Carlos belonged, was planning a garden for the client Fred as a part of the design challenge. For the garden design, Carlos kept explaining what a carbon nanotube is and searching related information, but other team members became visibly bored listening to him. As different interests and preferences were articulated, conflicts within the group emerged. Mary, in particular, actively expressed that she did not like Carlos' idea.

01	Mary:	So.. I think we wanna make sure his house is safe. So fence..
02	Carlos:	Ahhh..! ((with exclamation)) Carbon nanotubes are places where
03		detection systems are, [what] could be safer than that.
04	Mary:	I don't [know] what these are, I don't..
05	Carlos:	((cutting her off)) These are the detection systems so you can turn them off
06		during the daytime, but when he would be sleeping, [you can turn them on].
07	Mary:	I don't think..
08	Hadwin:	Why don't we just vote? Let's vote.
09	Carlos:	You just hate me!
10	((The team voted, but only Carlos' hand goes up. Hadwin was hesitating to put his hand up.))	
11	Carlos:	((aggressively)) Ok! If nobody wants me on the team, then I won't!!

This episode shows how problems associated with different interests and areas of expertise can lead to collaborative process problems. Carlos had high interest and knowledge in emerging science materials and therefore wanted to incorporate this area into the project (turns 2, 5). Mary, on the other hand, had no interest or knowledge in this area and therefore did not want to include it (turns 4, 7). Hadwin, noticing Mary did not like the idea, proposed voting as a strategy to end the argument. Carlos, knowing they will vote against him, sees the strategy as a personal affront (turn 9). When the team refuses to consider or synthesize his interests not the project, he feels devalued by the team and threatens to leave (turns 9, 11).

The tension between Carlos and the others continued to escalate after the first episode, eventually attracting the attention of one adult facilitator, who tried to resolve the conflict. She asked Carlos to explain his idea and prompted him to search for more information to help teammates better understand carbon nanotubes. Carlos found one website stating that carbon nanotubes are conductive materials. Attempting to mediate the problem between Carlos and Mary, the facilitator questioned the logic of using conductive materials for a garden and pushed the group to make evidence-based arguments and reasoning, as shown below.

12	Facilitator:	I'm thinking about 'conductive'. If it is conductive, can electricity go with
13		these materials, if it is lightening?
14	Carlos:	It is safer to be conductive because it goes through, because it won't pass
15		the lightning, but it would go down to the ground.
16	Facilitator:	So I really wanna know, because Mary was talking about, she doesn't feel
17		comfortable with that. Can we listen to her for a while?
18	Mary:	Because.. I don't.. You just said safer? What you just said really made me
19		freak out, that's not safe. 'cus if something went wrong, it could be very
20		dangerous.
21	Facilitator:	So I am actually, I am not sure about when I was talking about conductive, I
22		am not sure if it is better to have conductive materials when you are
23		designing things, or better to have insulated.
24	((continuous arguing about carbon nanotubes' conductibility between Carlos and Mary))	
25	Facilitator:	Check online and see..
25	Carlos:	((cutting off, with anger)) Nobody wants my idea!!

At first, the facilitator tried to lead the team to recognize that conductive materials could be dangerous based on her own scientific reasoning, by giving lightening as one example (turns 12-13). She tried to resolve the conflict by pointing out a flaw in Carlos' reasoning rather than trying to find a way to incorporate Carlos' idea into the design and account for potential dangers (turns 21-23). Carlos then had a strong negative affective response (turn 25). Although the facilitator tried to actively engage with the students, her approach at 'solving' the problem instead of helping the team to synthesize ideas and interests further diminished Carlos' interest in the group project. After this episode, Carlos became further disengaged from the design activities. He ignored discussions, positioned himself away from the group, and began reading a book.

Discussions and implications

The results show how problems can emerge from diverse individual interests and how these problems can lead to decreased engagement of individuals in the group project. Our analyses indicate that strong existing individual interests and diverse areas of expertise within a group can create problems with joint understanding, which may lead members to dismiss the ideas of others. Our microanalyses also show how strategies that focuse on logical decision-making processes (i.e., voting or logical questioning) can lead to further problems for a group (i.e., splintering), aligning with previous studies (e.g., Ortony et al., 2005). What remains to be understood is how to merge different interests into a shared project and how this synthesis would increase collective interest and collective engagement. Thus more work needs to be done on exploring how different interests and ideas can be negotiated and synthesized during collaboration.

This work has implications for the design of CSCL environments with regard to how we design activities to support the development of collective interest and help students resolve conflicts stemming from diverse interests. When designing learning activities, it is important to have flexibility to match with learners' different interests (Ainley, 2006) and incorporate their own goals (Lemke et al., 2014). When it comes to design, moreover, considering different perspectives is critical (Dym et al., 2005). Thus, learning activities may need to support the development of learners' expertise by embracing different interests. We also found that the importance of facilitators' roles to mediate learners' problems. When problems emerge, facilitators might be tempted to interfere and solve the problems, but it may be more important to support learners' ability to think from diverse points of view, to incorporate different interests, and to facilitate community involvement (Garcia & Morrell, 2013). Thus, in future studies, we will examine how to design CSCL settings to account for these implications and identify productive roles for facilitators within informal CSCL settings.

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Educational Affordances of Tablet-Mediated Collaboration to Support Distributed Leadership in Small Group Outdoor Activities

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Abstract: This paper investigates how distributed leadership emerges during tablet-mediated collaboration in an outdoor learning environment. We posit that one of the affordances of mobile technology is to mediate the distributed leadership that emerges among group members during small group activities. A collective case study was conducted to observe how children assume different types of leadership during collaborative tasks. The findings show evidence that supports the mediating role of tablet computers on the emergence of distributed leadership during a collaborative group task.

Introduction

Leadership is not a singular role that is held by one person during a collaborative task; rather, leadership is distributed and assumed by multiple group members across time and space. Different attributes of collaborative tasks require different leadership roles for their success, and, by doing so, this leads to diverse engagement (Gressick & Derry, 2010; Li et al., 2007; Mercier, Higgins, & da Costa, 2014). Our study focuses on how different dimensions of leadership are distributed among group members during a collaborative science learning experience. By analyzing peer interactions while using tablet computers, we explore how tablets afford capabilities for learners to assume leadership during observational inquiry activities.

Theoretical background: Distributed leadership and role taking

During a collaborative learning experience, leadership is a "a reciprocal social process, instead of the property of an individual (Li et al., 2007). Leadership emerges from social interactions, when a leader initiates an action and his or her followers respond to the initiated action (Li et al., 2007). Because leadership emerges from social interactions, leadership does not usually stay with one person; instead, different types of leadership emerge from different group members. Li et al. presents five dimensions of emergent leadership: Turn Management, Argument Development, Planning and Organizing, Topic Control, and Acknowledgment. Mercier et al. (2014) developed these dimensions further by synthesizing them into two categories: Intellectual and Organizational. The *intellectual* category is comprised of topic control and idea management and development; it is related to the content of the learners' discussion. The *organizational* category is related to managing and organizing discussions. Mercier et al. suggest that the nature and content of tasks may influence the distribution of emergent leadership among group members.

Discovering different types of emergent leadership can be interpreted as a person acquiring a role. Rowell (2002) illustrates how peers take on roles in a group activity during shared technological activities. For instance, if one assumes the role of manager, the others take on a supportive assistant role. Also, a student with the assistant role may choose to work in a different domain than the manager in order to assume more responsibility. By taking different roles, children assume different leadership for the success of a learning activity. Some studies on emergent leadership assign roles to engage learners in a collaborative learning environment. For example, Gu et al. (2015) assigned different roles, consisting of Starter, Supporter, Arguer, Questioner, Challenger, and Timer, to undergraduate students in order to engage them in the process of constructing knowledge collaboratively.

Educational affordances

Another concept related to tablet-mediated collaboration is educational affordances. From the varying definitions, we adopt Norman's (1988) definition: "The term affordance refers to the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used. A chair affords ('is for') support and, therefore, affords sitting" (p. 9). It is important to identify educational affordances of the technologies because, in many cases, technologies that are used for education are not necessarily designed with such purpose in mind. Hence, understanding the concept of affordance and analyzing which affordances are inherent within the device could help educators to effectively use the technology (John & Sutherland, 2005; Mishra & Koehler, 2006). In our study, we explored how a mobile tablet device mediates distributed leadership.

We presupposed that the tablet would play a role in helping distributed leadership to emerge among learners in a summer camp.

Methodology

A collective case study was conducted to see how young children (ages 9-12) collaborate and assume leadership during an informal learning experience. The study comprised four sessions in 2015 during iteration six of a larger DBR study (Zimmerman et al., 2015). In iteration six, each workshop session contained multiple groups. This study examines the interactions that took place among two groups of learners, resulting in total of four groups for observation. Group interaction was video-recorded using a standard video camera. We also asked some group members to wear GoPros on the head to collect additional videos. Video recording was our main data source to analyze peer interactions within each group and to identify how distributed leadership emerged during the task.

Study setting

The setting of the study was at an environmental center run by a land grant public university located in northeastern region of the United States. The center runs summer camp for hundreds of young children each year to help them learn about nature. The study was a one-hour session of a six-week camp program where children used tablets to experience and learn about trees. Children were led by a Naturalist on a guided tour during the study. One iPad Mini tablet was given to each group. For the first part of the tour, which lasted about 45 minutes, the Naturalist led children through the forest to learn about the life cycle of the trees. Five different stages of life cycles (seed, seedling, sapling, mature tree, and snag/dead tree) were explained during the Naturalist-led part of the session, with the assistance of a mobile app called *Tree Investigators*. The Naturalist prompted learners to observe the trees and read from the app containing a conceptual diagram of the tree life cycle and pictures and descriptions of each stage. *Tree Investigators* was designed with the theory of distributed cognition/intelligence in mind where we intended for students to use it to augment and interact with the nature around them as part of their cognitive activities (Hollan, Hutchins, & Kirsh, 2000; Hutchins, 1995; Pea, 1993). The second part of the tour was student-led activity where learners were prompted to use the app to take the photos of trees they identified in each life cycle stage. The children in groups freely explored the designated area to observe and take photos. Then they were prompted to create a personalized photo collage of the tree life cycle using their own photos. No restrictions were given in terms of iPad usage and turn-taking within each group.

Data collection and analysis

A total of 25 upper elementary learners were video recorded after obtaining informed consent and assent. There was a total of four sessions, and two groups were chosen for this preliminary data analysis. The focus of the study was observing how learners assumed leadership during the collaborative task, so only the second part of the camp experience was analyzed. The analysis focused on how and when learners took turns using the iPad and how they assumed roles and performed tasks in observational activities such as navigating and photo-taking.

Findings

Our analyses showed that the tablet device appeared to play some role in mediating leadership among group members. Since children were grouped in pairs, one child would typically assume the role of holding the tablet while the other did not use a device. Often, the child without the device would initiate the first move. To illustrate this finding, Michael and Nathan were looking for a tree's seed. Nathan held the tablet, and as such, had a specific role of holding the tablet. The tablet is important because it held all the information about the tree life cycle stages as well as a photo capture tool and checklist to verify the evidence for each identification. Hence, it was impossible to complete the task without the tablet. Because of the tablet, Nathan's role was clear: taking photos, organizing the next tree stage to identify, and checking the criteria for each life cycle. However, Michael's role and task were not as clear since he was not holding the tablet. Michael consistently showed leadership by searching the forest to find a tree specimen to photograph. Then, Nathan would take a photo of the specimen while Michael gave advice on how to maneuver the tablet. To illustrate, after taking the photo, Nathan (holding the tablet), read the app content to find the next tree life cycle stage while Michael led them through the forest.

Michael:	((gasps)) Look! A small pine cone. ((approaches the ground to pick it up)) We could make a picture of this. ((but leaves it on the ground)). It's really small just like lean down on it.
Nathan:	((bends a bit and takes a picture))
Michael:	Plus check on there, check on there, and then.

Nathan:	Oh that's perfect ((gets up) Okay.
Michael:	Okay.
Nathan:	((reads)) "Has a root, stem, and at least one needle"
Michael:	((whispers)) stem… ((looks around))

Nathan assumed the role of a photo-taker and content reviewer while Michael assumed the role of a navigator. Across the groups, often the child who was not holding the tablet would go ahead and look for the tree specimen while the one with the tablet focused on verification of the tree based on app content and creating the photo artifacts using the tablet. Using Mercier et al.'s (2014) term, Michael focused on organizational leadership while Nathan focused on intellectual leadership with app content.

Similarly, another group displayed consistent leadership distribution. In this case, Jason and Matilda (holding the tablet) are looking for seedling:

Jason:	Seedling now, seedling…Here, over here, right there. Can the camera see it?
Matilda:	((Bends down and sits to take photo as Jason monitors it))
Jason:	Right there, yeah got it ((Matilda seems to struggle and Jason helps)).
Jason:	All right, what's next?
Matilda:	Sapling ((points)).
Jason:	Let's see. That's a sapling ((as other group member points)). Do you want to use that sapling? Do you want to use this one?
Jason:	All right, I will try to find a…
Matilda:	Mature.
Jason:	Mature Tree.
Jason:	Here's one. Found one right here.
Matilda:	((Takes photo)). This tree has thick tuck thicker than around both of your hands.
Jason:	I will check ((goes over to the tree and tests it out using his own arms).

Similar to Michael and Nathan, Jason, who was not holding the tablet, took charge of navigating and looking for the appropriate tree specimen. Jason also initiated the task by asking Matilda to confirm which stage they are looking to identify next. Jason also assisted Matilda while she took the photo. Also, we found that the children collaborated by verifying the photo target in a different manner. When they located a mature tree, Matilda provided the criteria to verify whether the tree was indeed a mature tree. Then, Jason went over to the tree to physically verify what Matilda had just read. Both children were taking initiatives but in a different way to successfully complete a task.

Overall, these two excerpts provided evidence that the device and mobile app played a role in helping different types of leadership to emerge within a group. Learners voluntarily appropriated themselves to take roles that were different yet complementary. This is in line with Rowell's (2002) study where peers would strategize themselves to assume leadership roles for the success of the group. This study adds to Rowell's study and the studies on emergent leadership (Gressick & Derry, 2010; Li et al., 2007; Mercier et al, 2014) by suggesting that the device can afford to mediate emergence of distributed leadership in an outdoor learning environment. We were able to observe that turn taking and utlization of tablets elicited group members to assume different leadership roles. Having a personal device to share seems to be different from sharing a large device where children can interact together simultaneously. This shows that, instead of waiting for distributed leadership to emerge naturally, we could integrate personal devices into learning designs in order to promote and mediate distributed leadership skills which could enrich learner experiences.

Future study implications

Our investigation suggests that tablet devices can play a role in eliciting leadership among group members. Based on this result, we posit that different technologies and their uses could possibly afford elicitation of diverse leadership. We would like to expand this notion further by assigning different devices and/or technology-mediated learning methods to each member to investigate how different technological affordances influence the emergence

of distributed leadership. We suggest assigning roles by handing out different types of devices. For instance, a smart watch could be associated with the role of time-keeping and planning, a tablet could be associated with app content processing, and GoPros/cameras could be associated with artifact creation.

There were some limitations to this study. First, rather than observing student groups in a longitudinal manner, these data were collected during a single session. Having a "one-shot" study has its limitations since it cannot fully entail the group dynamics during the collaborative learning process. Second, since dimensions of distributed leadership were based on group discussions, there were not enough dialogue to code the data with the Li et al. (2007)'s coding scheme, suggesting a need to modify the coding scheme to fit an informal, summer-camp context. Lastly, we implemented GoPros to see if the GoPros played a role in mediating leadership roles. However, it seems that GoPros were too ambient for learners to appropriate any leadership roles. This shows that pedagogical consideration associated with educational affordances of a technology is essential in promoting leadership. Future research can focus on clearly delineating tasks or instructional methods associated with the devices to investigate their role on learning and emergent leadership.

With these limitations in mind, next steps in the work include analyzing and more cases for more valid findings and designing and conducting a new study which diversifies devices and assigns them to children in order to mediate emergent leadership. Through future study, we hope to investigate whether different educational affordances instantiated by different personal devices could mediate children to assume different types of leadership.

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Acknowledgments

Designing Science Curriculum for Implementation at Scale: Considerations for Diverse and Resource-Limited Settings

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Abstract: Designers of science curricula intended for broad use must take into consideration the diversity of students, teachers, and material resources available across various settings. While curriculum design literature gives some guidance for designers, most work in this area focuses on design by small design teams working on materials for relatively narrow contexts. To further inform the work of science curriculum designers, we conducted two retrospective case studies of curricula designed for large-scale use. Qualitative data were collected through document analysis and interviews with key design team members. Data were analyzed deductively and inductively. Here we focus on findings about the influence of policy and cultural context, and the ways in which the needs of target student and teacher populations are considered during curriculum development. The findings are useful to other designers concerned with bringing science content and practices to broad audiences of diverse learners.

Keywords: science, curriculum, scale, design

Introduction

Few studies have explored processes of design and development of science curriculum materials which yield deep understanding and rich learning performance at scale. Such curricula must reflect careful attention to the wide range of human and material resources likely to be available across diverse educational settings. A wealth of literature exists that describes high-quality *outputs* of educational design, providing both theoretical and practical guidelines in the form of models, heuristics and principles (e.g. Atkinson, Derry, Renkl, & Wortham, 2000; Davis & Krajcik, 2005; Gagne, Wager, Golas, & Keller, 2004; Van Merrienboer & Kirschner, 2007). These describe abstract features of effective final teaching and learning materials. Much has also been written about the process of designing instruction (e.g. Kemp, Morrison, & Ross, 1994), courses (e.g. Piskurich, 2006; Posner & Rudnitsky, 2005; Smith & Ragan, 2004), and programs (e.g., Loucks-Horsley, Hewson, Love, & Stiles, 1998; Wiggins & McTighe, 2005). With the notable exception of Walker's deliberative approach to curriculum development (Walker, 1990), however, there is a limited empirical basis for the literature on curriculum design *processes*.

Moreover, available literature guiding educational design processes is insufficiently fine-grained for concerns of scale, which involves more than reaching many users or regions (cf. Dede, 2006). We must also examine characteristics contributing to scalability along salient dimensions. Our view of these aligns well with those of Coburn (2003), who distinguishes the following dimensions: Depth: goes beyond surface structures or procedures to alter teachers' beliefs, norms of social interaction, and pedagogy; Sustainability: the curriculum's use can be sustained in adopting schools; Spread: it can expand to more schools and classrooms, also spreading reform-related norms and pedagogical principles; and Shift in ownership: the reform becomes self-generative, under authority held by districts, schools, and teachers to sustain, spread, and deepen reform principles themselves. To achieve success on these dimensions with continued positive impacts on learners is no simple task. It requires addressing key tensions influencing the practicality and effectiveness of materials across contexts. In this study, we examine strategies and processes used by successful designers to render designs implementable across the range of real-world settings common to educational practice.

Theoretical underpinnings

The analysis presented in this paper focuses on how design teams create supports for curriculum enactment that align with their understanding of the settings, resources, and constraints likely to be present during implementation. In this study, implementation is defined as "the process of putting into practice an idea, program, or set of activities and structures new to the people attempting or expected to change" (Fullan, 2007, p. 84). It can be described as consisting of three stages (Fullan, 2007; McKenney & Reeves, 2012): *Adoption* concerns the process through which a decision is reached to move forward with a particular innovation. *Enactment* pertains to

putting the innovation into practice. *Sustained maintenance* refers to actions taken to sustain the innovation under representative conditions.

Environments vary in their capacity to support the implementation of new curricula. The literature suggests a number of factors that impact capacity for implementation, including at the teacher, school, and environmental/cultural levels (Rogan & Aldous, 2005; Tao, Oliver, & Venville, 2013). Material resources include the physical condition of school facilities, library/laboratory/training facilities, consumable materials, textbooks and technological infrastructure, and exert profound influence on implementation. Similarly, the extent of human resources such as teacher capacity and administrative support, and access to networks and communities, often determine the sustained success of adoption or enactment of new approaches.

Additionally, educational settings differ along many dimensions (e.g., urban/rural/suburban, student socio-economic status (SES)), each of which has implications for curriculum implementation. For example, Fishman et al. (2011) found that the sustained use of a technology-heavy math curriculum was positively correlated with students' SES. A thorough understanding of the setting (and of the resources and constraints available) can be critical to the success of an instructional innovation.

Our work examines the design of K-12 science curricula intended for large-scale use. In this paper, we focus on the ways in which designers: (1) define the settings, resources, and constraints that will impact implementation, (2) attend to those when envisioning enactment, and (3) manifest their ideas about settings, resources, and constraints in the curriculum materials.

Methods

This study investigated the design practices that led to curricula with demonstrated evidence of success in (some of) the aforementioned scale dimensions. We asked: (1) *How did these designers define, and accommodate the settings and resources of the target users? (2) How did designers envision enactment and accordingly design supports, given their curricular goals and intended audiences?*

This data set includes projects completed at two US institutions with strong track records in curriculum design. The two cases analyzed in the current paper were: (1) a high school physics curriculum designed to highlight connections between the classroom and the workplace [pseudonym *Working Science*] and (2) an integrated science and literacy curriculum designed for grades 2-5 [pseudonym *Literary Science*]. Figure 1 provides an overview of the case selection criteria, data collection, and analysis methods.
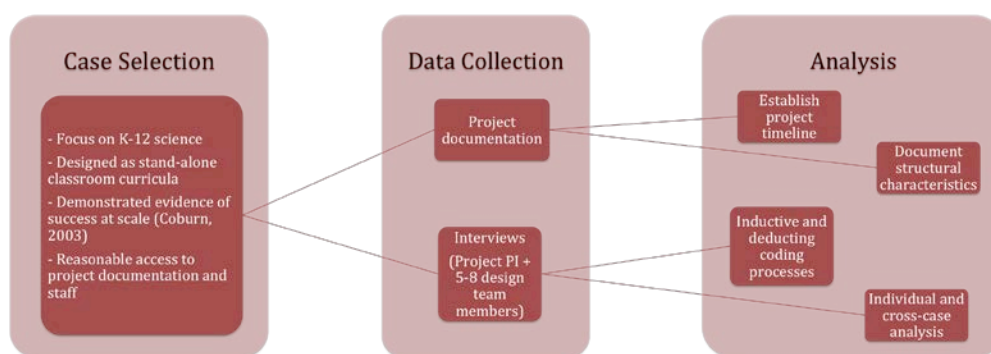
Figure 1. Methods overview.

The cases selected were each successful on two or more of these dimensions of scale: learner performance, depth of change, sustainability, spread of materials and underlying principles, or shift toward local ownership. The data set included project documentation and interviews. A wide range of document types were obtained, including grant proposals, annual and final reports to funders, evaluation reports, research reports and publications, curriculum materials (e.g., student and teacher books/guides), conference presentations, project memos, and project websites. Documents were used to develop a project profile including information about structural characteristics of the curriculum, a chronology of the design process, and the extent to which the project had achieved scale. Two rounds of structured interviews were conducted. First, an initial interview with the project PI and senior staff was held to confirm the results of document analysis. Following this, a second round of individual interviews was conducted with project designers, researchers/evaluators, and project leaders. These interviews investigated how designers considered their core intentions given various settings, resources, and constraints; how designers attend to those considerations when envisioning enactment of the curriculum; and how

attention to those considerations are actually manifested in the curriculum. Data were coded deductively into project-related themes and curriculum representations. Inductive coding then looked for emergent themes in designers' responses to implementation settings and resources. After the interviews, a second round of document analysis was undertaken for the purpose of triangulating findings from participant interviews and providing additional details about events, processes, or materials described during interviews.

Findings

Settings and resources
Table 1 describes the design teams' ideas about settings and resource considerations related to implementation, and intentions for addressing these considerations. In the section that follows, we describe how those intentions were translated into enactment supports for teachers and students.

Table 1: Designers' intentions related to settings and available resources for each case.

Curriculum	Settings	Resources
Literary Science (published 2006-2011)	• Students: Designed for all students, with a focus on making materials accessible for a diverse range of students including English Language Learners. • Teachers: Designed for diverse teachers, including new teachers and those without a strong science background. Designed to be taught "out of the box" (without professional development).	• Designed to provide students with access to potentially unfamiliar environments/ ecosystems (e.g., "Can we bring the forest into the classroom?").
Working Science (published 2006)	• Students: Designed for students without a strong science/math background, not interested in traditional physics courses, and likely in vocational programs. • Teachers: Designed for teachers with a science background but likely unfamiliar with an inquiry approach.	• Designed to work in classroom with limited financial resources. • Important to provide access to community resources (i.e., workplace connections).

Enactment supports
Two themes, emerging from inductive analysis, characterized each project's approach to the development of enactment supports (see Table 2). First, curriculum development work proceeds within the larger context of education culture and policy. These two projects were responsive to the cultural pressures in place at the time of their development. Second, each project was responsive to the needs of the students in the target population.

Table 2: Themes characterizing the development of curriculum enactment supports.

Comparison Theme	Relationship to larger movements and shifts in education/policy	Accommodate needs of non-typical science students
Literary Science	*Designed to accommodate increased pressure for literacy instruction in elementary school.* • Integrated literacy-science curricula can be implemented during literacy blocks. • Teacher support materials: (1) clearly define how much time is devoted to each discipline; (2) provide educative supports for elementary teachers more accustomed to teaching literacy than science.	• Materials address the needs of English Language Learners (e.g., limiting and focusing the introduction of new science vocabulary words). • Provides teacher supports for working with English Language Learners.
Working Science	*Responsive to the 'school-to-work' movement, science standards, and to increased interest in inquiry-oriented science.* • Educative materials support teachers in guiding inquiry. • Developers questioned their ability to change teacher practice. Quotes about 'getting teachers on our side' and 'may not be possible in the scope of our work'. • Teacher materials provide explicit directions for implementation.	Students not on the "academic track" • Embodiment of unorthodox materials ("job sheets"); student resource guide instead of text. • Focus on developing shared experiences (e.g., workplace visits) for under-resourced students.

Conclusions and implications

Our analysis highlights the influence of policy and cultural context, and the ways in which the needs of target student and teacher populations are considered during the development of curriculum intended for large-scale use. The study makes several contributions to the existing literature. First, our work contributes to educational policy scholarship by exploring how two groups of curriculum designers interpreted and responded to movements and trends in education, and highlights how designers can leverage policy shifts in ways that support (rather than place demands upon) educators. Second, our analysis explores design tensions and solutions related to the creation of enactment supports for diverse learners. Future work will examine additional design projects and the specific analysis, development, and evaluation processes behind the creation of enactment supports for diverse educational contexts.

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Acknowledgments

Interdisciplinary Computing and the Emergence of Boundary Objects: A Case-Study of Dance and Technology

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Abstract: Many educational interventions involving computer science and engineering have created interdisciplinary educational experiences to contextualize the learning. These efforts have begun to help diversify computing and engineering by encouraging young people who are underrepresented in these fields to consider them from a different perspective. Computing projects in these environments are often collaborative and require students with varying backgrounds and perspectives to work together. We propose that the coordination between the participants is facilitated in the presence of their differences through the computational artifacts they create, which serve as boundary objects. Furthermore, integrating art into these interventions promotes abstract thinking, enabling the boundary objects to flow more seamlessly between weakly and strongly structured implementations and interpretations. We examine this proposition within a case study of a dance and technology workshop. We highlight how students and leaders negotiated and accepted differences within their perspectives and interpretations of the dances they created.

Keywords: boundary objects, computer science, engineering, broadening participation

Introduction

Interdisciplinary learning environments involving computer science and engineering are beginning to create more diverse learning opportunities. From e-textiles (Buechley & Eisenberg, 2008) to augmented interior design (Camarata, Gross, & Do, 2003), there are a plethora of options for working across fields. One avenue of this interdisciplinary work is through STEAM (science, technology, engineering, arts, and mathematics) interventions. This type of work has the possibility of engaging those with artistic interests, while providing them with exposure and education in the realm of computer science and engineering. In particular, we will focus on the combination of dance and technology, which gives students an embodied form of expression (Hanna, 2008). Others have successfully coupled technology and dance within the educational domain, integrating dance into the Alice programming environment (Leonard & Daily, 2014). The TechDance workshop is another effort in this domain. We create a community of learners (Rogoff, 1994) combining leaders from varying expertise, with students who have diverse backgrounds in order to create technology enhanced dance performances using microcontrollers. With the myriad of students and educators that often work together in these educational endeavors it is important to understand how the various backgrounds and interests of the participants affect the collaboration and learning that takes place. Within TechDance we saw the students and leaders using their dance performances as boundary objects. These objects supported collaboration, enabled students and leaders to learn about each other and from one another, and created opportunities for the participants to take on different roles. We discuss boundary objects as a framework and then illustrate our findings within TechDance.

Boundary objects

Within an interdisciplinary curriculum involving collaborative work, the objects that the students and educators create together serve as boundary objects in which various interpretations and values are embedded. Star and Griesemer (1989) present boundary objects as an analytical framework to interpret the collaborative practices surrounding Berkeley's Museum of Vertebrate Zoology. They used the framework to describe how scientific findings, which often had vastly different meanings and implications depending on the social world, could have coherence (Star & Griesemer, 1989, p. 132). They further expand on these characteristics:

> Boundary objects are objects, which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual site use. These objects may be abstract or concrete. They have different meanings

in different social worlds but their structure is common enough to more than one world to make them recognizable, as means of translation. (Star & Griesemer, 1989, p. 393)

Star (2010) emphasizes that the term go beyond interpretive flexibility of objects to include understanding how the object influences the "structure of informatic and work process needs and arrangements" within communities as well (p. 601). Star clarifies that boundary objects were originally created to describe the phenomena in which opposing forces were able to work together without reaching consensus. She points to the importance of scope and scale of the boundary objects in order to understand the affordances of the object based on its materiality and infrastructural properties (p. 613).

This definition has been applied in the educational domain in a few contexts. For example, boundary objects were used as a framework for examining the success of curriculum change that progressed in spite of conflicting powers (Hultén, 2013). The framework has also been used in the context of individual courses, such as understanding the success of an authentic science course in which students wrote for science journals, bridging them into communities outside of their schools (Polman & Hope, 2014). Wenger also examines learning at boundaries in the context of communities of practice (1998). Outside of these individual explorations, Akkerman and Bakker (2011) completed a literature review to offer insight on conceptualizing the use of boundary objects and boundary crossings in the education domain. Their analysis reveals four ways in which learning occurs at boundaries: *identification*—understanding the diverse perspectives and practices in relations to one another; *coordination*—how the cooperation between the perspectives and practices is regulated; *reflection*—creating opportunities for one to think about and expand their perspectives in relation to others'; and *transformation*—creating new practices based on the intersection of boundaries (p. 150). Throughout TechDance we saw how the students and leaders *identified* differences in their perspectives, created a structure for the *coordination* between the disciplines and perspectives within the workshop, and created opportunities for *reflection* through their discussion of differences. Due to the brevity of the workshop described in our case study, we did not witness new practices being developed. However, through our analysis we reveal how the boundary objects served to foster abstract thinking amongst the students and leaders during collaboration periods in which the objects were more weakly structured. The abstraction of the objects allowed them to work together while having disparate concrete views of the objects on an individual level.

Case study: TechDance

This paper examines a five-day workshop, TechDance, in which middle and high school female students worked with dancers, choreographers, engineers, and computer scientists, to produce technology enhanced dance performances. The workshop was designed to engage students who might not normally participate with computer science or engineering, so we worked with a community organization who focuses on providing underserved girls with experiences and guidance as they become young women. The workshop participants consisted of 13 girls from the community organization, and 8 adult leaders—4 CS/engineers and 4 dancers/choreographers. Two of the researchers participated as technology leaders during the workshop. Our data collection comprised of surveys, which covered demographics and student perspectives of computing, and qualitative data, which included observations, audio debriefs with leaders at the end of each day, and post-study interviews with six students and the leaders. Two researchers reviewed and analyzed this data for emergent themes, which they then solidified into codes (Saldaña, 2012). After initializing the codes, the researchers reviewed the data, identified any missed or controversial codes, and resolved any disagreements. We focus on the qualitative data for the purposes of understanding the boundary objects in this context.

The diversity of students and leaders within the workshop created a community of learners within the workshop in which all members had expertise to offer as well as opportunities to learn. The leaders, who all had either an arts or technology background, had distinct contributions to the project. For example, one of the dance leader's professional portfolio focused on choreographing dances around the world, while another specialized in both dancing professionally as part of a company and teaching dance professionally. The leader who taught dance, often taught young African American girls, giving her more experience than any of the other leaders in this domain. Furthermore, the diverse backgrounds of the students created learning opportunities between all the participants. The students shared their expertise in their values as they integrated them into the dances.

TechDance began with the leaders introducing the students to tools, concepts, and techniques that they could use during the less structured project phase of the workshop. With a few exceptions, the students had little experience with dance or technology. Throughout the workshop the students worked on producing three dances, with technology and choreography they themselves produced. The three themes of the dances were, bullying, self-esteem, and destruction of nature. These themes were arrived at through a series of activities that scaffolded the students articulating and reflecting upon issues that they cared about. Through these exercises we also had the

students thinking of how they could express these emotions using the technology and dance techniques learned earlier in the workshop. The final activity they completed had them identify what they wanted to represent in their dances and how they wanted to represent it using technology. We then used their responses to group them. As with most group work, there was not always a perfect match between the students. Despite mismatches, students were still able to create value driven designs. The expressive yet interpretive nature of dance helped the students think abstractly and manage their differences enabling them to collaborate.

Emergence of boundary objects

When the groups were first formed they worked in their groups to brainstorm. The bullying group was comprised of two girls who wanted to work on bullying and one girl who wanted to represent a dictatorship. After each of the girls talked about their ideas, the girl who wanted to represent a dictatorship was able to find common ground. She remarked on how their ideas were not that different because each of their scenarios went from a bad situation to a good situation, and the expression would be similar. This realization enabled them to get over the first bump in their collaboration and move forward discussing how they would use the dance and technology to express the *bad* situation and the *good* situation in their dance. Even before the dances and technology were realized, we witnessed how the dance acted as a boundary object through the students' negotiation of themes, helping them bridge their differences. While each of the girls had a robust definition of the meaning of their dance, they were able to talk about it in an abstract way when they were working together across their perspectives.

Having the students express their differences created an environment in which many of the students could recognize that art and technology can be interpreted in many different ways. During the post-interviews one student remarked, *I enjoyed that we might like different things about what we do — Student 5*. They also recognized these differences throughout the workshop as they caused tensions as the varying opinions emerged:

> At certain points in the dance, um, there were certain things that not everybody agreed on, so we had to change a few things in the dance. It ended up working out but it was just, um, a bit hard to agree on certain movements in the dance at certain points. — Student 1

The need to collaborate on producing the dance brought contrasting views to light giving students opportunities to negotiate between their differences. However, they did not necessarily reach a consensus in order to move forward with the decisions they had to make. The students had to *coordinate* between the various differing perspectives. A student in the deforestation group reflected on how her group members thought about the dance:

> One of my group members, her original theme was about bullying, and so [to] incorporate that into the nature theme she said that humans would bully nature so she took it that way. And then, so that was a difference. And the other group member, she thought a lot about the animals in nature and protecting the animals so that was her main concern. — Student 1

It was through these differences in perspectives of the dance itself that students were able to *coordinate* despite their differing interests. These particular differences between students' views had an effect on what they wanted to incorporate and accomplish with the work they put into the dances. When one student was asked about how the other students contributed to her dance, she stated:

> Some of our ideas were different so we had to figure out how to come together…Like, two of them were similar, but not really. So we had to figure out where to put it all into the dance…everybody did like one part inside another part. — Student 5

The dances became a conglomeration of the various aspects that each student contributed, but by working together they were able to achieve cohesion. They were able to understand each other's perspectives, and in this instance, weave their own additions to the dance into the greater structure.

The dances were also a boundary object for the leaders who viewed the dances from their own perspective. One leader remarked on her interpretation,

> They brought up…these global issues [that] also impact girls on a micro level and they impact them in their everyday life. And it's something that they do and want to build solutions for. They just need to have the know-how and education and resources to do it. — Dance Leader 1

The leaders often saw the societal context in which the issues the students raised were situated. One dance leader saw the dance as a tool for empowering these students to talk about the issues they want solved in the world.

Throughout the workshop we saw how the leaders' different backgrounds led them to approach the various aspects within the dance or technology differently. One of the dance leaders remarked on her experience understanding the technology through the students' interpretation of the technology:

> I basically just sat back when you guys were doing your, uh, your lecture about the Arduinos and the breadboards and putting it together. And then I just circled around the kids when I felt like they had, like, kind of figured out what they were creating and then asked them. What did you create? What are you making? What does that do? So I feel like it also helped me to know if they knew what they were talking about and it also taught me what they're talking about. — Leader 2

Here electronics portion of the dance was perceived differently: from the technology leaders' perspective, it was a teaching tool that uncovered how the students were thinking about the microcontroller; while from the dance leaders' perspective, it was a learning tool which the students could use to explain the concepts to them. The technology artifacts offered those coming in with different backgrounds different affordances.

Conclusion

Boundary objects enabled us to understand how the participants, with varying backgrounds, interests and expertise, could still create value driven dance performances. The collaborations within the TechDance workshop were facilitated through the dances and computational artifacts that the students and leaders created together. These boundary objects were a form of artistic expression that enabled the participants to collaborated using abstractions while embedding different individual values. From learning about one another's backgrounds to learning about one another's expertise, the boundary objects served as learning tools for the entire community of learners. The boundary objects highlighted the various values and interests of the students and educators and helped to identify the learning opportunities between the diversity of participants. With further research, boundary objects could prove to be an important analytical framework to understand how fostering abstract thinking about boundary objects affects collaboration and value driven learning in these interdisciplinary interventions.

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Acknowledgments

Unpacking Social Factors in Mechanistic Reasoning
(Or, Why a Wealthy Person is Not *Exactly* Like a Grey Squirrel)

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Abstract: Mechanistic reasoning in social domains is understudied. We speculate that the ways that students reason about social phenomena share enough similarities with how they reason about physical and life sciences that we can use existing work on mechanistic reasoning to characterize students' explanations of social phenomena. We apply an existing framework for analyzing student reasoning about life sciences to students' explanations of a social phenomenon relating to urban planning. In comparing these analyses, we propose a component of student reasoning that may be specific to reasoning about social phenomena: social factor backing. We show that incorporating this component into the existing framework providers a fuller account of our data. Finally, we discuss why we think this element could be important for future studies of students' mechanistic reasoning about social phenomena.

Keywords: mechanistic reasoning, science education, social science education

Introduction

Mechanistic reasoning, or reasoning systematically through how and why underlying factors and relationships give rise to a phenomenon (Machamer, Darden, & Craver, 2000), is a valuable form of human thinking. It allows people to systematically explain and predict events in contexts as wide-ranging as workplace and organizational dynamics (e.g., Senge & Sterman, 1992), traffic jams (e.g., Wilensky & Resnick, 1999) or fluctuations of populations in ecosystems (e.g., Jacobson & Wilensky, 2006). This type of reasoning is increasingly becoming a focus of schooling across disciplines. In particular, science education reforms such as the Next Generation Science Standards call for integrating causal, mechanistic thinking as a crosscutting concept in science instruction (NGSS Lead States, 2013). Along a similar vein, the NCSS recently released The College, Career, and Civic Life (C3) Framework for Social Studies State Standards (NCSS, 2013), proposing new K-12 social studies in which they emphasize 'complex causal reasoning'. Although we have some ideas about what mechanistic reasoning looks like and how to support it in science classrooms (e.g., Russ et al., 2008; Schwarz et al., 2009), research has strikingly tended to separate out reasoning involving people as "social" or "socio-cultural" reasoning that is distinct from—or even in opposition to—"scientific" reasoning based in logic and mechanism (e.g., Lee, 2012; Pedrett & Nazir, 2011). As such, we know very little about what mechanistic reasoning looks like in contexts that include people as humanized components of systems, or how students' reasoning about those mechanisms compares to mechanistic reasoning about natural phenomena (i.e., not involving humans). As we work to prepare students to solve complex, multifaceted problems in a world where the social and natural spheres are intimately interconnected, we need to better understand what mechanistic reasoning is and what it involves in order to design curricula and instruction that better supports students in this kind of crosscutting mechanistic reasoning. Here, we aim to characterize students' mechanistic accounts of natural and social phenomena using the same framework in order to identify similarities and differences that contribute to a general theoretical model for mechanistic reasoning and suggest important analytical differences that can help bridge our understanding of mechanism from the natural sciences to the social sciences.

What is a mechanism in the natural sciences? In a synthesis of work from the philosophy of science, Machamer, Darden, and Craver (2000) define a mechanism as: "entities and activities organized such that they are productive of regular changes from start or set-up to finish or termination conditions" (p. 3). Russ et al. (2008) apply this definition to identify elements mechanistic reasoning in student discourse, including identifying entities, or "the things that play roles in producing the phenomenon" (p. 14); and a set of elements that together are about "characterizing entities": identifying activities, properties, and/or organization of those entities. For example, a student seeking to explain how and why they could smell popcorn inside their classroom when it was being popped in the teacher's lounge could identify that both the popcorn odor and the air are made of *molecules* that are constantly moving and bouncing off each other. They might also reason that the popcorn odor molecules are warmer than the air molecules and therefore have more energy. Though not yet a full causal account, this activity of identifying and characterizing the entities involved in producing a phenomenon are a critical part of reasoning through a mechanism.

However, the nature of the entities that students characterize, and subsequently use to reason with, may differ across science contexts. In the physical sciences theses entities are often individual agents like molecules. But in the life and earth sciences the units that students identify and reason with are more often *relationships* between entities, properties, and behaviors, such as "grey squirrels can eat acorns" (Krist, Schwarz, & Reiser, under review). It is these relationships that are most productive for students to think with as they account for phenomena occurring in complex environments such as an ecosystems (c.f., Vattam et al., 2011). We follow Author 2 et al., and use the term "factor" to describe the unit that students identify and subsequently use to reason, whether that factor be an individual agent or a relationship. Due to these observed variations in science contexts, we wondered if we would see new types of factors and reasoning about social phenomena. Because social phenomena often involve values and decisions, we speculated that the way students identify and characterize factors in this domain may have additional dimensions related to human decision-making.

In this paper, we seek to explore ***the nature of the factors that students identify*** and ***how they characterize them*** as they construct mechanistic accounts of social science phenomena. We do so by analyzing college students' responses to a question about the relationship between income and commute times. Our preliminary analyses show that students do in fact identify and unpack factors as an important part of their mechanistic reasoning. However, students also reason through how the entities in the system (people) make decisions that as part of their explanation of the phenomenon. We discuss how this affects both our theoretical understanding of mechanistic reasoning more generally and how we can better support students' use of this dimension in their mechanistic reasoning across domains.

Methods

To examine elements of students' mechanistic reasoning in a social science context, we used written responses from undergraduate students during a unit on urban planning. During the unit, students interacted with a NetLogo (Wilensky, 1999) model that allowed them to build a city by drawing in various types of zones (residential, industrial, etc.) and constructing major highways and public transit lines. While running the model, they could monitor several variables, including average commute time, average income, and distribution of income levels across the city. After the unit, we gave students a post-test that included the question, "Can you explain how a high-income person's income might make their commute time longer than a low-income person's?" Students wrote short answer responses that were between 1 and 4 sentences long.

To analyze these data, we utilized Krist et al.'s framework for differentiating the relative complexities of students' mechanistic accounts. We draw on their notion of a "factor" as whatever unit students identified and used to reason through a phenomenon. We speculated that students would likely identify complex factors, such as entity-property relationships. We also noted where students "unpacked" those factors, or reasoned through how the implications of those relationships over space and/or time gave rise to the observed phenomenon (Krist et al., under review). We highlight four student responses that exhibited varying levels of mechanistic reasoning in order to show contrasting cases (Table 1). In the following section, we account for our analysis of these four responses, discuss similarities and differences between the two datasets, and articulate the degree to which the analytical framework can help us make sense of them.

Findings

In the first response, SS1 identifies two factors; that low-income people live in the city, and that wealthy people live in more spread out suburbs. However, while both of these factors are important parts of a full explanation, SS1 does not unpack and say *why* these two factors would lead to differences in commute times for the two population groups. In the second response, we see that SS2 identifies two factors as well. One is the same as SS1, and the other is different: that higher income people typically live in suburbs, and that they work downtown. Additionally, this student unpacks the relationship between these two factors, and explains that the reason why higher income people have higher commute times is that these two factors combined lead to *longer drives*. Finally, there is a probabilistic element in SS2's explicitly says that high income people *typically* live in the suburbs. We see this response as similar to a response to the life sciences question in which a student claims that red squirrels *typically* cannot eat acorns (though it is always possible that some of them might have randomly mutated in a way that allows them to do so). So far so good, and we can see that applying Author 2 et al.'s framework helps us identify elements in student responses.

However, we see something different in SS3's response that we think might be related to the probabilistic element in SS2's response. SS3 identifies the same two factors as SS2 (that wealthy people can live in suburbs, and that they might work downtown), but goes on to explain that wealthy people '*are able to afford*' living in suburbs. We feel that this is an important part of the reasoning, but we struggle with classifying it under the existing framework: it is not exactly a factor in itself, because it cannot be unpacked on its own or even with other

factors. It would not, for instance, be convincing or good mechanistic reasoning to say, "People can afford to live in suburbs, therefore they have longer commute times" (although some students did that.) Rather, stating that wealthy people 'are able to afford' living certain places seems to offer a justification or backing to the 'wealthy people might live in suburbs' factor by explaining why, for some members of this population, this factor exists. In other words, where the color of a squirrel has a probabilistic effect on what the squirrel can do, the wealth of a person has a probabilistic interaction with what that person *chooses* to do.

Table 1: Four responses to the prompt about urban planning

| Poor people live in dense industrial centers, while wealthy people live in more spread out suburbs. (SS1) | They typically live in the suburbs and work downtown so *they have longer drives for commute times.* (SS2) | A wealthy person's income can make their commute time longer if *they live farther away from their jobs.* For example, some wealthy individuals live in suburbs, but their jobs are in industrial cities. Because they have a higher income, they are able to afford living in these communities, but their commute time is longer than a poor person who happens to live near industrial areas. (SS3) | A wealthy person's income could make their commute time longer because they can afford a car, which means *they could get stuck in traffic*. They also have the ability to choose where they live based on safety, quality schools, lots of parks, etc - and the *place that fulfills all of these requirements might be far from work.* (SS4) |

This is even more evident in SS4's response: Similar to SS3, SS4 connects wealthy people's wealth to their 'ability to choose where they live'. However, SS4 goes on to list potential wants and desires in wealthy people that could lead them to make a particular choice: *'safety, quality schools, lots of parks, etc.'* Finally, SS4 gives the underlying factor that actually answers the question: they might choose to live in a place that is 'far from work.' However, in order to get to this factor, they had to reason through what they assume that people want, and under what conditions people might (or might not) do that.

We believe that this process of reasoning through the conditions and probabilities of human choice is a distinct, and important part of mechanistic reasoning about social issues. In order to fully analyze and assess students' mechanistic reasoning about social issues, we therefore suggest that it is necessary to add an extra step to Author 2 et al.'s analytical framework: a process of backing or defending the factor identified, based on the choices that entities have in capacity of their property, and of considerations of the wants and desires that led them to make choices that resulted in the factor. We call this process "social factor backing." We propose that this process consists of:

   a) identifying a factor, such as "wealthy people tend to live in suburbs," that contains an entity and at least one of the defining properties of the entity (e.g., a person + wealthy);

   b) recognizing that that factor (that wealthy people live in suburbs) comes out of the relationship between entity and property (e.g., wealthy people can afford to live in suburbs *because* they are wealthy), not because of random arrangement or assignment of natural factors;

   c) walking through the rationale of the entity for making *that particular* decision (and not any of the other possible decisions) by connecting its decision to assumptions about the entity's underlying wants and desires (e.g., wealthy people want to live near parks and good schools, and can afford to do so); which leads to:

   d) the statement of the factor, which has now been backed (e.g., therefore some wealthy people live in suburbs). This factor can then be unpacked as normal.

The additional step to Author 2 et al.'s framework is step b) in which students explicitly reason through what it is about the entity + property relationship that provides choice(s), and in c) in which the student account for the particular wants and needs in the entity that led to making that decision. Revisiting SS2 with this new construct, we can now more clearly begin to see where this response is lacking with regards to mechanistic reasoning: SS2 correctly identified the two factors (wealthy people live in suburbs, and they work in cities), and unpacked them ('so they have longer drives'). But SS2's response neither states that they live there because their wealth allows them to (b) or that they live there because they *chose* to (c). So while the overall claim in the explanation is true, we think that it fails to capture some fundamental, and to us, important underlying *social mechanistic* reasons: that people do things for different reasons because of the complex interplay between their inner wants and desires, and choices afforded to them by their properties.

Implications and conclusion

In this paper, we showed that it can be productive to use mechanistic reasoning to understand students' reasoning about a social phenomenon. It helped us identify which factors that students reasoned about when they explained the phenomenon, and it helped us structure an analysis of how these factors taken together caused the phenomenon to occur. However, the existing framework we used did not allow us to fully capture the kind of reasoning that students did about how entities have a range of options because of something inherent in them, and how they then reasoned about the decision making process. By adding 'social factors backing', we were able to more fully account for this part of their reasoning. We believe that this could be an important component of reasoning mechanistically about social phenomena, and that a consideration to the choice- and options-elements may be important in the study of, and design for learning activities about, social mechanisms.

Our treatment of students' reasoning did not consider the important connection between language and ideology (Fairclough, 1995, 2003; van Djik 1998), and treated the use of 'poor' as equal to 'low-income'. Lexicalizations like these may express important difference in reasoning, in particular relating to social factors, like the wants and needs of social actors. Student responses also implied that certain outcomes were more desirable than others, but these aspects of thinking were ignored for the purpose of this analysis. Future work should include considerations to these value-laden aspects of language use.

The C3 framework's focus on 'complex causal reasoning' suggests an increasing focus on reasoning in social sciences education at the K-12 level. Research in science education has for decades improved our understanding of what causal reasoning about the natural sciences looks like. The early findings in this paper suggest that mechanistic reasoning can be a productive lens on students' reasoning in social sciences. Future work will aim to improve our understanding of social mechanistic reasoning with an eye towards the larger educational goals: building curriculum to support and develop this kind of mechanistic reasoning; exploring this with different social phenomena, and building meaningful assessments of student learning.

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Conceptual Fluency: Switching Between Pre- and Post-Threshold Assumptions of Molecular Dynamics

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Abstract: We present preliminary analysis of chemistry graduate students' and secondary chemistry teachers' assumptions about mechanisms of chemical phenomena, around a set of threshold concepts. Chemistry education literature largely identifies pre-threshold assumptions as naive/alternative conceptions not particularly useful in understanding chemical phenomena. In the context of molecular dynamics, a threshold is considered to exist between thinking deterministically vs. probabilistically. We argue that (a) a deterministic perspective is as useful as a probabilistic one, (b) even experts implicitly exhibit (do not lose) deterministic assumptions, (c) probabilistic mental models are built on top of deterministic models, using multiple instances of the phenomena of interest, and (d) expertise involves willfully switching between pre- and post-threshold assumptions.

Introduction

Research on misconceptions and alternative frameworks has occupied a great deal of effort over the past decades. These endeavors characterize and differentiate between the ways in which students misunderstand the natural world and the models that science offers to explain it. At this point, there is no longer any doubt that alternative conceptions occur. Voluminous evidence supports claims that experts reason differently than novices (e.g. Kozma & Russell, 1997), and that some misconceptions are robust (diSessa, 2006).

Posner et al. (1982) introduced the theory of conceptual change to explain how students' conceptions change when new ideas and evidence are introduced. According to this theory the changes are analogous to the two-phase model of conceptual change in science (Kuhn, 2012; Carey, 1999). Borrowing terminology from Piaget, they called the first phase 'assimilation'. This occurs when learners use concepts they already possess to rationalize new ideas and evidence. The second phase, called 'accommodation', is more radical. It occurs when existing concepts are inadequate to rationalize new ideas and evidence, and the learner must replace or reorganize conceptual understanding. One thread of research proposes a parallel between the historical evolution of concepts in the discipline of science and the development of concepts in a child's mind (psychological recapitulation or the theory-theory view (Carey, 1999; Karmiloff-Smith, 1988; Vosniadou et al., 2008). A similar thread suggests that conceptions (alternative and correct) belonging to ontologically different categories (e.g. direct causal vs. emergent notions notion of a phenomenon, looking at a concept as a 'substance' vs. a more dynamic 'process' notion of the same) are more robust and difficult to remove/rectify, than ontologically similar ones (two different 'direct causal' notions of that phenomenon; Chi, 2008).

Although such models of conceptual change, and the curricular approaches they inspire, stress a qualitative understanding of scientific concepts and an overall constructivist perspective towards learning, many of them downplay or undermine the role of prior knowledge. They do so by considering that, as a result of rational thinking by the learner, correct conceptions will be chosen over (and will replace) misconceptions whenever the learner encounters conflicting ideas (Smith et al., 1993). This has propagated a problematic model of the mind that concepts can be replaced like physical objects.

The 'knowledge in pieces' (diSessa, 1993) perspective on the mechanism of conception and conceptual change suggests that a person's knowledge system consists of numerous simple elements of knowledge, called phenomenological primitives (*p-prims*). These *p-prims* are formed as a result of superficial interpretations of experiences of physical reality by novices, and are organized gradually into a conceptual network. In novices, this network is poorly organized, whereas in experts (through conceptual change), these pieces of knowledge are systematically integrated into larger and more complex systems of knowledge.

Alternatively, Mortimer (1995) has illustrated that a learner can hold several alternative concepts in the mind, and that context influences, but does not determine, the formation and exhibition of such concepts. At any given time, the learner's mind holds a distribution of different related (yet alternative and even contrasting) concepts. The concepts can be characterized, and each learner has a different distribution of these, called a conceptual profile. The conceptual profiles approach mildly denies the very occurrence of conceptual change, and maintains that alternative concepts can not only co-exist but also are necessary as they are often applied pragmatically in corresponding contexts.

There does not seem to exist a consensus among learning scientists (diSessa, 2006) on how conceptual change occurs, what are the mental mechanisms involved, and how can this process (of conception) be intervened with, if at all! A first step in resolving some of this conflict is to establish evidence for whether naïve assumptions or superficial interpretations are indeed replaced by more sophisticated assumptions or conceptual networks when conceptual change occurs, or if sophisticated assumptions and conceptual networks exist alongside naïve assumptions and superficial interpretations that continue to be relied upon. Considering that there are different forms of expertise, specifically expertise as researchers in a discipline and expertise in teaching a discipline, we designed a study to examine what assumptions are relied upon by experts who can be expected to have changed conceptions to at least some degree, if conceptual change occurs.

We present a preliminary analysis from a think-aloud and eye-tracking experiment showing that experts exhibit contradictory assumptions about mechanisms of chemical phenomena depending on the nature of the prompt. We then illustrate how a mixed distributed cognition and neural network model of knowledge representation may provide a possible mechanism of conception and conceptual change.

The experiment

We selected related pairs of assumptions that have been studied sufficiently and are considered to exist on opposite sides of a threshold concept (Meyer & Land, 2006). Threshold concepts are recently and increasingly robustly characterized as conforming to the following main features: 1) they are difficult to grasp, i.e., troublesome, 2) people's thinking becomes transformed when they cross over a threshold, 3) understanding a threshold concept generates interrelations between concepts previously considered unrelated, 4) the transformation is irreversible, and 5) the concepts serve as boundaries that mark a discipline (Loertscher et al., 2014; Talanquer, 2014).

Working within the discipline of chemistry, the threshold concept selected for our exploratory study is characterized by a transition that Talanquer describes as "from a centralized causal process to an emergent process schema" (Talanquer, 2014). This threshold concept centers on transformations of matter. Four related pairs of assumptions appear to straddle the threshold: (a) static vs. dynamic views of molecular behavior, (b) deterministic vs. probabilistic views of chemical phenomena, (c) direct causal vs. emergent views of mechanisms that underlie processes, and (d) object vs. interactions views of structure and properties of matter. Preliminary analysis reported here concerns (a) & (b) only.

Sample and methodology

Eight chemistry graduate students (GS2-GS9) from a university and six experienced secondary chemistry teachers (T2-T7) from schools in the Northeastern USA participated in this study. Participants were recruited from these two populations because they have different kinds of expertise (chemistry content expertise, and expertise in teaching chemistry), and the goal of this study was to examine expertise in chemistry considered broadly. All participants were individually presented with the same visuals, prompts and questions on a laptop screen, and were asked to talk the researcher through her/his entire thinking process. Figure 1 shows the protocol for one of the three experiment trials.
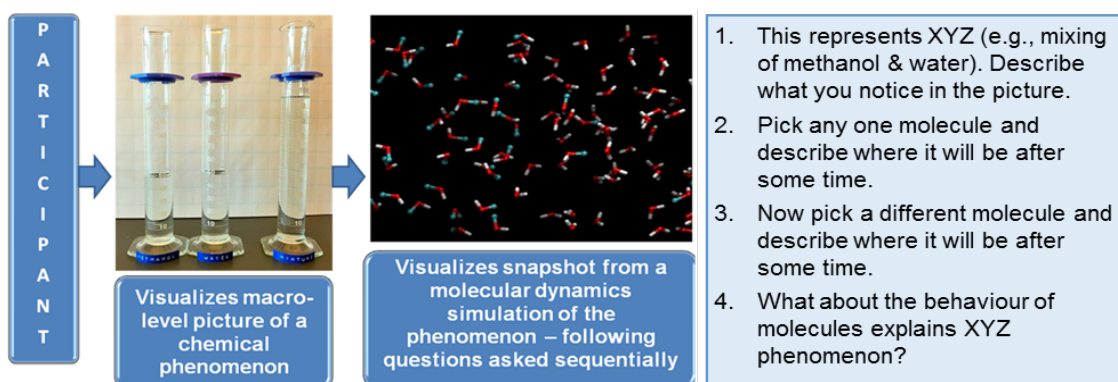
Figure 1.Experiment trial

Questions 2 and 3 were designed to stimulate reliance upon deterministic assumptions, the snapshots were static pictures and the question asked about the immediate timeframe ('what happens next?'). Question 4 was designed to stimulate probabilistic assumptions, as the question requested mechanistic explanation of how molecular-scale dynamics conflate to account for an emergent phenomenon. There were three trials, each involved presentation of four visual stimuli corresponding to a specific chemical phenomenon: a photograph of the macroscopic

phenomenon, then three identical copies of snapshots of a molecular dynamics simulation with different questions asked for each of the identical stimuli. Three phenomena were presented: (a) mixing of methanol and water in the liquid phase, (b) formation of ice crystals from liquid water, and (c) combustion of hydrogen gas. Audio and video recorders were used to record participants' explicit thought processes for further analysis. Eye-tracking (Tobii TX2-60) was also employed to capture implicit behavior-level correlates of the deterministic-probabilistic thought processes, as well as differences between those correlates, if any.

Analysis

The think-aloud audios were transcribed. Trains of thought within responses to each question for each participant were characterized as indicating reliance upon either 'deterministic' assumptions or 'probabilistic' ones, based on indicators summarized in Table 1. Other codes, and eye-tracking results are not reported in this paper.

Table 1: Preliminary qualitative coding scheme for think aloud data.

Mental model/code	Indicators/Markers
Deterministic	Linear explanations of reaction mechanisms (uncertainty of events ignored), explained molecular/reaction behavior deemed **certain**
Probabilistic	Non-linear explanations of reaction molecular behavior, uncertainty/affecting factors considered, particular behavior of molecules/reactions as a **function of probability**

Findings

For the 'single molecule behavior' questions (Q2 & 3 - Figure 1, total six questions across three trials), eight participants provided probabilistic explanations (e.g. Transcript 1). They indicated the 'likelihood' of a molecular event depending on the properties of the picked molecule and its surrounding, and other possible factors that could affect that reaction. Four participants provided deterministic explanations (e.g. Transcript 2). One participant (T4) tended to use probabilistic and deterministic perspectives equally often interchangeably.

1. Transcript 1 (GS7): So.. the oxygen molecule near the bottom right, I don't know where it'll be, but it won't be where it is right now. And.. uh.. it may not be an oxygen molecule if it collides.. um.. with a hydrogen atom or molecule.. um.. with enough force to break the bond. That's about it.

2. Transcript 2 (T2): Let's pick another one.. to the right of those methanols, there are three water molecules in close proximity and the same thing I think would happen. The more negative oxygen side would be attracted to the more positive hydrogen side of the other two water molecules. And therefore they would move close together. That's it.

For the 'mechanism' questions (Q4 - Figure 1, total three questions over all trials), all participants (except T6) tended to provide 'likelihood' explanations. Interestingly, these overall seemingly probabilistic answers 'emerged' out of different small and isolated instances of deterministic explanations of molecular events. In summary, most participants relied upon both deterministic and probabilistic explanations while answering the 'single molecule behavior' as well as 'mechanism' questions. Thus, it seemed difficult and inappropriate to call a participant either a deterministic or a probabilistic thinker.

Discussion and conclusions

In this study, the 'single molecule behavior' questions were intended to cue for pre-threshold (deterministic) assumptions, while 'mechanism' questions were intended to cue for post-threshold (probabilistic) assumptions, if the participant had developed these assumptions.

Preliminary findings indicate that participants employed both pre- and post-threshold assumptions quite pragmatically. Deterministic assumptions were often exhibited among some participants when behavior of a single molecule was in focus. Meanwhile, the same participants seemed to employ probabilistic assumptions when explaining macro-level manifestations of molecular interactions. Deterministic models of phenomena offer executive control over variables by lowering cognitive load, and allowing externalization, (through representations and actions, Kirsh, 2013). Probabilistic models provide holistic understanding of chemical phenomena. Below we briefly discuss a possible general mechanism of conception indicating how assumptions lying on both the sides of a threshold can co-exist/exhibit. We present here a theoretical proposal based on recent advances in cognition. Our preliminary empirical findings described above are used to illustrate the promise of the argument.

A neural network model of conception

Neurons in the brain are connected to each other, forming a web. The networks formed out of these connections can exist in multiple activation states. Several neuro-imaging experiments and studies in distributed cognition show that specific activation patterns in the brain are coupled with specific elements in the external world (such as entities, phenomena, and their representations or models). There may not be a direct one-to-one correspondence between activation patterns and the external world, but the coupling has biological correlates.

We imagine a conceptual network supported by (possibly built upon) this biological neural network. Unlike in a semantic network, experiences of worldly events are coded as activation patterns in this conceptual neural network, so are scientific experiences of worldly events - through either direct exposure to those phenomena and/or multiple external representations and models of those phenomena (Pande & Chandrasekaran, 2016). In our view, a collection of related activation patterns is exhibited as assumptions/generalizations built upon relatively concrete experiences. Any new experience around corresponding worldly element leads to a reorganization of the existing network (or activation patterns), thus, changing the assumption. The extent of this change would depend on the (virtual) size of the previous network - richness and diversity of previous experiences. This property of the networks makes some assumptions robust, for instance the assumption among children (and even adults) that 'the earth is flat' as deemed robust by previous research. We argue that this, and assumptions alike, are not only retained in the network but also used implicitly.

This neural network model makes possible understanding 'alternative conceptions' as natural conceptions that can have validity under some circumstances, endowing them with utility. Thus, they should not be viewed as 'things to be dealt with'. There is no qualitative/mechanism level difference in the formation as well as nature between alternative and so called 'correct' concepts. This view is sympathetic with the *p-prims* as well as conceptual profiles approaches. From our perspective, the more diverse one's experiences around a concept, the richer the network/activation patterns may be. Expertise, therefore, is redefined as the ability to willfully switch between multiple assumptions/activation patterns. In other words, the conceptual neural network perspective predicts conceptual fluency rather than conceptual change, as a model of learning.

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Let Kids Solve Wicked Problems... Why Not?!

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Abstract: We describe the first iteration of design experiments that aim to assess an instructional framework we call Preparation for Future Collaboration, which consists of three main phases of learning activity: 1) individual cognitive preparation in the content to-be-learned, 2) discussion/collaboration of ideas generated during preparation, and 3) direct instruction. We conducted an experimental study *in situ* in three fourth-grade classes in a public school in Singapore, manipulating the way that students prepared for a collaborative activity in a topic in environmental education. Future analyses will include using measures of student artifacts to assess the effectiveness of different forms of preparation on both the process of learning and post-activity outcomes. In this paper, we share two cases to illustrate student ability to generate solutions to a wicked problem.

Keywords: preparation for collaboration, collaborative learning, complex problem solving

We should put a sensor on the ground so that when someone litters there will be a small space that will open and the litter...will drop into a place with treadmills on the ground and a thin magnetic roof so the cans that have been littered will be attracted by the magnetic roof... when litters are on the treadmill a smart computer can identify the plastic and paper and pick it up with fake metal hands. (Fourth-grade female student and male student, 2015).

Introduction

The above quote comes from two Singaporean students who discussed how to solve a typical wicked problem on waste production and disposal during a class lesson on environmental sustainability. Despite being a highly teacher-centered and assessment-driven educational culture (Hogan et al., 2013), Singapore's education system is shifting towards student-centric instruction. With the shift towards 21st century learning, students should be given opportunities in class to not only apply content that is taught, but to engage in learning activities that involve creative thinking, authenticity, and idea generation. In this paper, we present work from the first iteration of a series of design experiments (Brown, 1992) being conducted in Singaporean classrooms that are founded on a theoretical framework we call Preparation for Future Collaboration (PFC). At the core of PFC is designing individual preparatory tasks that aim to invoke the generation of ideas and naïve conceptions in ways that lead to effective collaborative discussion and learning. We further explicate our framework below, describe the design of our study, and share preliminary findings based on two cases of student collaborative work.

Preparation for Future Collaboration (PFC)

The notion of PFC involves activation of particular cognitive processes through the design of the instructional task, subsequent engagement in peer collaboration, and then teacher-led instruction following. This approach encourages students to freely discuss ideas with a peer, rather than imposing structures on their interactions (e.g. through collaborative scripting or prompting, or training on how to collaborate). We are examining two ways to cognitively prepare for collaboration: a) studying/working with the canonical forms/representations of a topic and b) generating one's own ideas before learning the canonical forms. In both cases, the preparation promotes a different degree of "readiness" for learning in the subsequent collaboration. According to the Preparation for Future Learning paradigm, preparing by generating knowledge promotes readiness to learn in a future lecture by helping students to: differentiate prior knowledge in ways that draw attention to deep principles of the concepts (Schwartz & Martin, 2004; Schwartz, Sears & Chang, 2007), and become sensitive to both the deep structural and surface features of the concepts (Schwartz, Chase, Oppezzo, & Chin, 2011), which then helps to consolidate knowledge during the subsequent lecture. PFC similarly addresses how preparation influences readiness to learn in a future task, however, our interest is in learning in a future collaboration, prior to receiving direct instruction.

The PFC model is theorized across three phases. We borrow from Kapur and Bielaczyc's (2012) work on design principles for Productive Failure to show how the mechanisms of generation, exploration, and consolidation and knowledge assembly spread across the PFC phases, as shown in Fig. 1. Ultimately, our conjecture is that the instructional context drives the learning processes that occur during preparation, which drive the process of collaboration, which affects learning during the direct instruction.

Instructional context (degree of generative activity in learning tasks) → *Preparation* (Exploration and Generation) → *Collaboration* (Exploration and Generation and Consolidation and Knowledge Assembly) → *Receiving Direct Instruction* (Consolidation and Knowledge Assembly)
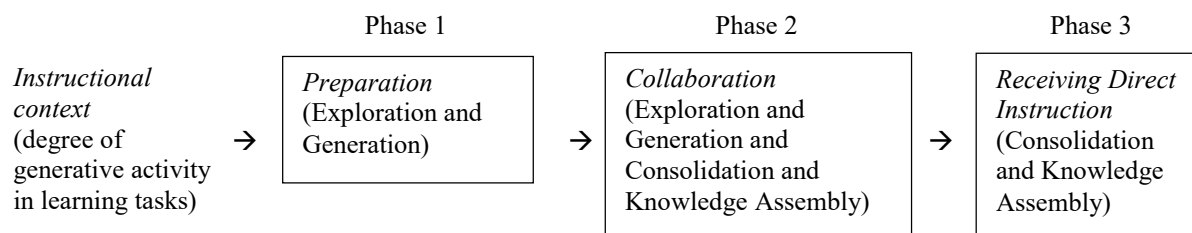
Figure 1: Phases of the Preparation for Future Collaboration (PFC) approach.

Lam's (2013) prior work investigating different forms of preparing to collaborate has shown similar post learning outcomes from both generative and non-generative preparation, however, the degree of learning during the collaboration differed across the types of preparation (unpublished data). In this paper, we share two cases from the current study to further unpack student collaborative work.

Complex problem solving and wicked problems

According to Funke (2001), complex problem solving has two main features: *connectivity* and *dynamics*. *Connectivity* refers to links between the different variables within a problem, and includes the complexity that each variable entails. Real-world problems (described below regarding our study) can be addressed through a variety of complex solutions, and each solution typically has its own set of interconnected variables. For example, for a problem of excessive waste being produced in a community, a solution focused on reducing waste could stem from individual action (e.g. by producing less, by reusing more, by recycling), which could be influenced by a government policy imposing a quota on waste production, which might encourage communities to organize ways to educate residents about the problem. *Dynamics* refers to the fluctuations that arise within a problem, which signal changes that develop over time. For instance, the solution of a government ban on plastic bags could lead to the long-term effect of producing less plastic waste. However, as communities shift away from plastic bags, there might be an increase in the use of paper bags subsequently increasing paper waste, or a shift towards using reusable bags, leading to the development of a new material. The connectivity and dynamics of such problems often makes them messy, and it is difficult to determine "right/wrong" solutions, thus deeming them "wicked" problems (Hung, 2013). The work on complex problem solving is mostly conducted in older populations (Ventura, 2014; Wickman, 2014). The shift to 21st century learning in K-12 education has emphasized the ability to transfer problem-solving skills (OECD, 2013), and students will be required to engage in complex, real-world problem solving when they enter the workforce (Fournier, 2002).

The present study

Our interest was to investigate how primary school students would engage in complex problem solving, while testing the Preparation for Future Collaboration instructional approach. We designed a problem question that focused on the growing production of waste in Singapore, a country with a great scarcity of landmass. Students were introduced to the problem and given information on the country's space constraints for landfills. They were also presented with the concepts of "reduce, reuse, and recycle," as aids to solve the problem. Students participated in all three PFC phases. We present two cases of student paired collaborative work from the study.

Methods

We used an experimental design to test how two different kinds of preparation would affect collaborative learning and problem-solving outcomes in three fourth-grade classes. The experiment was run *in situ*, and replaced the teachers' original activities for the topic.

Student and school sample

A total of 100 students across the three classes participated. The school was a typical public primary school, and one of the lower ranked schools in its area (1). Our larger project targets low-achieving students, but we have included classes at a range of levels in our first iteration.

Procedure

The PFC lesson was conducted in 1.5 hours. The same researcher facilitated the lessons in all three classes, while 1-2 research team members and the classroom teacher helped to manage the students. Students were first briefed on basic logistics of the study and then listened to a 15-minute presentation by the instructor-researcher introducing the problem question. Students were then randomly assigned to a condition: Select a solution or

Generate solutions. In the Select condition, students individually selected one of three given solutions to the problem and wrote down why they chose the solution. In the Generate condition, students individually generated as many solutions as they could in the given time period. All students worked for 15 minutes during the preparation phase. At the collaboration phase, students were randomly assigned a partner in the same condition. They discussed their individual ideas with each other and then jointly recorded onto a worksheet their "best" solution. Students worked collaboratively for 35-40 minutes. The instructor then engaged students in a whole class discussion by allowing them to share (by volunteering) their collaborative solutions out loud, and afterward presented information about various elements of complex problem solving (e.g., sharing multiple perspectives, complexity/simplicity of solutions, feasibility of solutions, cost-effectiveness, etc.).

Analysis

The larger study will include a post-problem-solving activity that measures problem-solving and transfer outcomes, and we will conduct quantitative analyses of the individual, collaborative, and post-activity measures to compare the two conditional groups. However, here we share two cases of student collaborative work from the generate condition in order to highlight some of the ways that students solved the wicked problem. We present each case of written solutions and our interpretation of the comprehensiveness, novelty, and feasibility of the solutions (2), and also provide excerpts of the student discourse to illustrate negotiation of ideas.

Findings

Case 1:.Our quote above was taken from a pair in a mid-level class. The students also wrote about making "new stuff" out of disposed plastic and reusing paper and they introduce the idea of recycling ash in landfills to "make it into a flower vase and use it as soil." For *comprehensiveness*, this pair's use of details to describe their high-tech solution is noteworthy. They mention a way to handle metal ("cans" being "attracted by the magnetic roof") and using a smart computer to differentiate materials. They describe a "sensor on the ground" to detect trash and using treadmills to transport trash to the appropriate places. In addition, they address what to do with recycled material, such as make "coins" from melted metal. Regarding *novelty*, compared to the other pairs in our sample, this pair's solution was unique. Many pairs mentioned separating the types of recyclable material, but into the existing recycle bins in Singapore. This pair weaves elaborate use of smart technology into their solution. For *feasibility* (that a solution is adaptive to reality), although complex and costly, such a solution is not outlandish. The idea to make soil out of ashes, in fact, aligns to one of Singapore's strategies, in which non-toxic ash of incinerated waste is dumped on an off-shore landmass and covered with a layer of soil to form a self-sustaining green landscape (see http://www.nea.gov.sg/energy-waste/waste-management/semakau-landfill).

The student dialogue included frequent turn-taking and negotiation of ideas, with little to no external guidance to facilitate their interactions. Excerpts are included below:

Excerpt 1	Excerpt 2
S1: The litter will go inside, then go on a treadmill and then *[imitating machine noises]*, all the cans will be *[imitating machine noises]* attracted from the magnetic...	S1: The waste can be put in—
	S2: Container.
	S1: —the landfill. To the landfill—
S2: How are they gonna do that? How you know, how you know you gonna do that? How they know how to do that?	S2: Landfill.
	S1: —into a landfill or put it in a volcano.
S1: So you must dig the whole Singapore ground. And then puts like a sensor and then every time someone litters... a door open, drop inside.	S2: What? How can they be transported into a volcano?
S2: Okay, I think I agree on that also.	S1: Cannot ah?
S1: You agree?	S2: Ya. ... *[skipped utterances]* ...
S2: Ya, write down.	S2: Go to, go to erm Indonesia for that.
	S1: Ya, put it into the Indonesia volcano.

Case 2: In this case, students from a low-achieving class discuss how recycled items can be donated to "poor people" to essentially start small businesses, whereby they remake the items into new things for sale. The students write about donating recycled items to poorer countries so that people can earn money. They also address how they, themselves, can save money by using recycled items to make gifts. In additional, they include the idea that such practices could motivate people to continue to recycle. For *comprehensiveness*, this pair's solution centered on different ways of using recycled materials to earn money for the poor. The level of detail contrasts the first pair, but is still elaborated with several separate ideas (e.g., make "things" to sell; buy food; build houses; buy pencils, books, toys, phone; buy gifts) and the idea of motivation to sustain new practices. For *novelty*, similar

to pair 1, the solution was unique relative to the sample, in particular, with regard to the altruistic focus on reusing recycled material to help the poor or to make gifts for others. Finally, the solution is highly *feasible* because it requires few resources and is a low-cost solution.

Conclusions and implications

Despite the typical highly teacher-centric instruction, i.e., first learning the "right" answers and then applying them to problem questions, our experience has shown that a task designed to first elicit students' naïve conceptions of yet-to-be-learned topics can lead to substantive interesting collaborative work. Our early analysis has shown that grade 4 primary students are capable of collaboratively generating interesting and elaborate ideas to solve a wicked problem, with little teacher intervention or direct instruction on common elements of complex problem solving. In the next iteration of our work, we will improve the design of the learning activities based on initial findings, examine how different types of preparation affect the collaborative process, and investigate how the PFC instructional design influences performance in novel problem-solving activities.

Endnotes

(1) Singapore uses an educational streaming system that relies on student performance on national exams.
(2) These three factors were borrowed from Galati (2015), which provides a comprehensive guide to asses difficult-to-judge solutions to complex problems.

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Effects of Implicit Guidance on Contribution Quality in a Wiki-Based Learning Environment

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Abstract: Learning within the scope of collaborative knowledge construction with Wikis offers opportunities for triggering socio-cognitive conflicts through controversies. Since the nature of discussions between users in Wikis is not easily recognisable, we were investigating the effects of visual highlighting as controversy awareness information. In this study we wanted to enable $N = 81$ participants to produce contributions of higher quality due to focused selection towards relevant contents. We conducted both qualitative and quantitative analyses on Wiki contributions. The addition of visual highlights indicating controversies reinforced students to direct their attention towards important contents discussing the study's subject matter. When their selection behaviour was positively influenced it resulted in higher quality and more elaborate contributions to discussion threads and to the final revision of an article. We conclude that unobtrusive implicit guidance can facilitate collaborative knowledge construction processes and outcomes.

Introduction

The processes of collaborative knowledge construction with Wikis can be difficult and challenging to users by causing frustration for learners (e.g. Capdeferro & Romero, 2012). This can be either due to its structural setup that is unfamiliar to many first time contributors or the manifold options such a system offers where anybody can edit virtually anything at anytime from anywhere. As a consequence, Wikis provide a fertile ground for controversies and socio-cognitive conflicts to occur. Controversies that are constructive and grounded on the exchange of opinions and different points of view on a specific topic provide opportunities for triggering learning-relevant processes and resulting in higher learning outcomes (e.g. Johnson & Johnson, 1979). These kinds of controversies can induce socio-cognitive conflicts that can be beneficial for learning (e.g. Mugny & Dosie, 1978), by triggering equilibration processes of accommodation and assimilation of new knowledge artefacts into one's individual cognitive system (Piaget, 1977).

In extensions to the individual learner's perspective on socio-cognitive conflicts, conflicts between the socio-technical system and the cognitions of a collaborative user base are explicated in the theory of *co-evolution* in collaborative knowledge construction (Cress & Kimmerle, 2008). Every individual's cognitive system that is participating in collaborative knowledge construction provides potentials for possible conflicts to occur while internalizing or externalizing socially shared artefacts from or into a Wiki as socio-technical system (e.g. Oeberst, Halatchliyski, Kimmerle & Cress, 2014). Collaborative knowledge construction processes with the ability to induce conflicts in either system can mutually influence each other.

In Wikis lie potentials for collaborative knowledge construction with regard to desirable constructive controversies and socio-cognitive conflicts that can be beneficial for a number of learning processes, such occurrences should be made more salient to the user. One approach to achieve this is the implementation of implicit scaffolding measures, such as providing representational guidance (Suthers, 2003) and additional cognitive group awareness information (Bodemer, 2011). Representational guidance has proven to be effective on having an impact on group and individual performances during collaborative tasks by directing participants with external representations, such as minimal obtrusive textual or visual contextual cues (e.g. Chun & Jiang, 1998). Especially the use of representational guidance implementations making use of graphics in computer-supported collaborative learning showed potentials of resulting in higher quality written texts as outcomes (e.g. Janssen, Erkens, Kirschner & Kanselaar, 2010).

In addition to that, cognitive group awareness tools that are focused on gathering and visualizing knowledge-related contextual cues have been successfully implemented as implicit guidance measures to structure collaborative learning processes (e.g. Bodemer & Dehler, 2011). It has been showed that implementations of tools that make specific contributions more salient provide the opportunity to strengthen a group's influence on others and foster learning processes as a result (e.g. Buder & Bodemer, 2008). In large scale online discussions additional visualisations have been proven as effective to implicitly guide readers by promoting a more selective reading behaviour and consequently result in better learning outcomes (e.g. Buder, Schwind, Rudat & Bodemer, 2015). Adding visual support for increasing salience towards discussions about controversial opinions or contradictory

evidence can support the induction of socio-cognitive conflicts. These conflicts have the potentials to initiate restructuring processes of one's own cognitive system as well as within the socio-technical system that is used for collaborative knowledge construction.

In previous analyses Heimbuch and Bodemer (2014, 2015) reported that specific highlighting of discussions in Wikis with the objective of promoting controversy awareness guides learners towards most relevant contents. This implicit guidance was the result of a more focused selection towards relevant information and furthermore lead to measurably higher positive learning outcomes. Other Wiki-related research has been focused on identifying qualitative indicators by means of article revision metrics (e.g. Halfaker, Kittur, Kraut & Riedl, 2009) or the usage of content analysis for exploratory classifications of discussion page contributions (e.g. Schneider, Passant & Breslin, 2011), but without analysing and comparing the quality of individual contributions. Thus far, it was still unknown what effects additional controversy highlights to a Wiki discussion page have on the quality of the individual contributions to an article and the corresponding discussion threads. Therefore, we conducted detailed qualitative analyses on article and discussion thread contributions of this Wiki-based study where additional visual highlighting aids as implicit guidance have been implemented.

Method

This experimental study has been conducted in a controlled laboratory setting with $N = 81$ university students ($M_{age} = 21.70$, $SD = 2.76$), mainly recruited from studies of Applied Cognitive and Media Science. They were randomly assigned to one of three versions of our learning environment, separated by privacy screens. They had to contribute to a pre-existing article and discussions. Due to technical issues at the experiment's editing stage, some of our analyses had to be performed with a total number of $N = 79$ participants.

The independent between-subjects factor consisted of three experimental groups reflecting different levels of implicit scaffolding through additionally visualised cognitive group awareness information on the occurrence of content-related controversies. Every group's Wiki had the same Wikipedia-like structure of the discussion page and identical contents inside the discussion threads. Participants had the task to edit an article on theories of mass extinction events of dinosaurs (*"Cretaceous–Paleogene extinction event"*). The study was divided into two phases: (1) reading the original article and corresponding discussions and (2) contribute to self-selected discussions and edit the article. The control group was provided with a Wiki article and discussion view which was similar to Wikipedia. The other experimental groups had additional visual highlights to the discussion page in form of visual controversy awareness information on the thread title level.

We conducted qualitative content analyses (Mayring, 2014) on the final edits of the individual Wiki articles and on the discussion replies of each participant. The finally derived coding schemes and category formations originated both from deductive and inductive procedures. Wiki article categories have been assigned deductively in accordance with Wikipedia's guidelines for evaluating an article's quality. Categories with regard to a discussion reply's content quality have been formed in an inductive procedure.

Results

In the following we will present the immediate effects on the contribution quality on the level of discussion threads where the controversy awareness indication was implemented. We further explore the indirect effects on the article level where knowledge artefacts needed to be transferred from the materials inside the different types of discussions.

By using a tertile split on the categorised discussion reply data, over all experimental groups and participants, 30.86% of all participant contributions were rated as lower quality, 58.02% as medium quality and 11.11% as high quality contributions. These numbers are total aggregates of categories associated with discussion reply quality. Reply quality was composed of *Neutrality* (acknowledging both opposing arguments), *New Aspects* (introducing new knowledge artefacts) and *Summarising* (integrating summaries of preceding discussion). Aaggregated quality ratings for reply contributions are presented in table 1.

Table 1: Frequencies (and percentages) of cumulative overall quality ratings of discussion thread replies.

	No highlight	*Controversy highlight*	*+ Status highlight*
Lower quality	12 (44.44%)	5 (18.52%)	8 (29.63%)
Medium quality	13 (48.15%)	19 (70.37%)	15 (55.56%)
High quality	2 (7.41%)	3 (11.11%)	4 (14.81%)

Over all groups and participants, 16.46% of all final articles were rated as lower quality, 51.90% as medium quality and 31.65% as high quality edits. These numbers are total aggregates of deductively assigned categories based on Wikipedia's article quality evaluation guidelines. Article quality was composed of *Referencing* (using references for article changes), *Structure* (fitting into the article's structure), *Neutrality* (integrating neutral points of view) and *Relevance* (editing is meaningful for the article). Aggregated article quality ratings are presented in table 2.

Table 2: Frequencies (and percentages) of cumulative overall quality ratings of the edited article.

	No highlight	*Controversy highlight*	*+ Status highlight*
Lower quality	5 (19.23%)	2 (7.41%)	6 (23.08%)
Medium quality	15 (57.69%)	16 (59.26%)	10 (38.46%)
High quality	6 (23.08%)	9 (33.33%)	10 (38.46%)

Discussion

When wikis are used for the production of socially shared artefacts in learning environments to foster the processes and outcomes of collaborative knowledge construction, the structures of a Wiki and the amount of information can be challenging for students. Virtually everybody can change any contents at any time in a Wiki which in turn can lead to the occurrence of controversies about contents that can subsequently induce socio-cognitive conflicts. In the present analysis we examined how the quality of contributions has been affected by adding visual controversy information to relevant discussion threads.

We found that highest quality contributions were marginally more frequent when the level of controversy awareness information was raised by providing additional indication on the resolution status. We could also see that when controversy awareness without additional status information was provided the most contributions of medium quality could be found, as well as the lowest number of participants who did not summarise relevant preceding discussions.

Although the numbers were only marginal, we identified the highest overall quality article in the experimental group that has received the most detailed level of controversy awareness and status information. But we also see a rather positive effect for the experimental group that did not receive the controversy status information, since they produced the smallest number of lower quality articles. These findings that are in favour of the effects of the more general information on the mere occurrence of controversies can be due to similar effects that have been found in previous Wiki-related research on collaborative knowledge construction. Medium levels of incongruity of information between the individual cognitive and the socio-technical system have been proven to be the most beneficial for learning (Moskaliuk, Kimmerle & Cress 2009) as well as medium levels of redundancy fostered external accommodation processes (Moskaliuk, Kimmerle & Cress, 2012). The findings of this present analysis are line with research that medium levels of supportive manipulations to scaffold learning processes are beneficially for a number of collaborators.

Finally, in conjunction with our previous quantitative findings (Heimbuch & Bodemer, 2014) these results show that additional representations of controversy awareness information can be effective for the resulting knowledge artefacts. This implicit scaffolding that is designed to help Wiki users to focus and select important contents has shown to be beneficial for effective learning and the outcome in terms of higher quality knowledge construction artefacts.Although this experimental study has been conducted with individuals in a laboratory setting, due to the deployed scenario of Wiki-based knowledge construction the potentials of implicit guidance should be considered for further research on collaborative knowledge construction environments. These findings are relevant for the learning sciences, especially for designing and implementing scaffolding interventions for computer-supported collaborative learning environments.

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Learning to Argue: The Role of Peer Assessment

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Abstract: The present study explored how peer assessment may influence the development of students' skills in constructing written arguments. Twenty-two college freshmen participated in this qualitative research to provide feedback on their peer's written arguments about popular psychology topics. Constant comparative analysis of multiple data sources revealed three main categories of feedback that students provided: cognition-based, metacognition-based, and affection-based. While receiving cognition-based feedback had the most impacts on how students would later evaluate others' work, those who had previously provided metacognition-based feedback were more likely to make observed progress in constructing arguments. This work adds to our understanding about the complex nature of peer assessment and proposes a potentially effective approach to facilitate students' skills in written argumentation.

Keywords: peer assessment, argumentation, feedback

Introduction

Peer assessment is an educational arrangement where students evaluate their peer's performance and provide feedback to each other (Topping, 1998). Fostering a culture of collaborative learning, engagement in peer assessment allows students to be in charge of their own learning (Kollar & Fischer, 2010). This not only motivates them to be more actively involved in the classroom but also helps them to be more reflective on their learning performance. Ultimately, students become more proficient in self-assessment and metacognition (Cho & MacArther, 2010). Considering its various learning benefits, peer assessment has been broadly employed in higher education and incorporated into the classrooms in different disciplines (Strijbos & Sluijsmans, 2010).

However, not all peer assessment provides positive learning effects. Several main factors may contribute to the learning outcomes of peer assessment, including the frequency and levels of detail in the feedback (Gibbs & Simpson, 2004), the nature of the tasks to accomplish (Topping, 2009), and instructional support provided (van den Berg, Admiraal, & Pilot, 2006). While in recent years a significant number of studies have evaluated approaches to structure peer assessment (e.g., Cho & Shunn, 2007; Orsmond, Merry, & Reiling, 2002), further research is needed to expand the scope of this line of research to explore how peer assessment may affect various aspects of learning (van Zundert, Sluijsmans, & van Merriënboer, 2010).

The present study explores how incorporating peer assessment may influence students' learning of argumentation. Argumentation is a social and verbal means of trying to resolve a conflict or difference that exists between two or more parties (Sampson & Clark, 2008). Constructing arguments requires individuals to analyze data and rationalize its use as evidence for a claim (Sandoval & Millwood, 2005). Previous research has shown that students experience difficulty in generating evidence-based arguments in both the sciences and social sciences (e.g., Acar, Turkmen, & Roychoudhury, 2010). As students tend to overlook the importance of argumentation and are often confined to only one perspective, engaging students in productive argumentation in the classrooms is particularly challenging (McNeil, 2008). With an overarching goal of exploring the role of peer assessment in written argumentation, the present study investigates three research questions:

1. What types of feedback do students provide when assessing peer's written arguments?

2. How does engagement in peer assessment relate to the development of argumentation skills?

3. What is students' perceived effectiveness of peer assessment?

Methods

Context and participants

Twenty-two college freshmen at a large public university in the Midwestern U.S. participated in this study (15 females and 7 males, M_{age}=18.20). They were all from at-risk backgrounds (5 African American, 4 Hispanic, 13 Hmong) and enrolled in the university's TRiO program, which provided extensive academic support for under-represented students to navigate through college. The study was conducted in an introductory psychology course that focused on developing students' cognitive and metacognitive skills. The curriculum was primarily centered on collaborative learning activities to foster students' critical thinking and self-regulated learning. None of the participants had taken any psychology courses prior to this course.

As part of the curriculum, written assignments were designed for students to critically evaluate different sources of information, construct evidence-based written arguments, and engage in peer assessment (see Table 1). Instructional support was developed to help students understand and practice writing arguments as well as evaluating other's writing. In addition, they were asked to reflect on their writing processes and experience in peer assessment in a journal every week. A whole-group discussion was led by the instructor at the end of every other week to help students further reflect on their learning experience.

Table 1: Timeline of instructional design on written argumentation and peer assessment

Content	Timeline	Activity
Introduction to written argumentation and peer assessment	Week 1	Group practices
Topic 1. Is development gradual and continuous, or abruptly in separate stages?	Week 2	Written Assignment 1
	Week 3	Peer assessment 1
Topic 2. Which form of learning, *conditioning* and *observational learning,* is more effective in scenarios such as classroom management and business?	Week 4	Written Assignment 2
	Week 5	Peer assessment 2
Topic 3. Do you think we have one general intelligence or multiple intelligences?	Week 6	Written Assignment 3
	Week 7	Peer assessment 3
Topic 4. Which psychological theory do you think best characterizes our personality?	Week 8	Written Assignment 4
	Week 9	Peer Assessment 4
Summary and debrief	Week 10	Group discussion

A detailed rubric was provided to guide students' own writing and evaluation of others' work regarding both the general quality of their writing as well as the content and structure. Rather than adopting a single-assessor approach, this study was designed to have each student receive feedback from two peers for more learning benefits (Cho & Shunn, 2007). To reduce the potential negative influence on learning outcomes, the grades students received from their peers were not counted toward their course grade.

Data collection and analysis

Data sources included four components: feedback that students provided to their peers; feedback that students received from their peers; students' written arguments; and students' weekly reflection journals. A qualitative approach, *constant comparative analysis* (Strauss & Corbin, 1990), was employed to integrate the different sources of data and identify main themes that may emerge. *Moodle*, an online course management system, was used for students to submit their own work and evaluate others'. All data were exported from Moodle and entered into NVivo 10 for analysis. Data analysis underwent an iterative process to establish credibility.

Findings

Research question 1

Three main categories were identified to capture the feedback that students provided: cognition-based, metacognition-based, and affection-based (see Table 2). In particular, *cognition-based feedback* entailed three levels: *corrective*, *confirmatory*, and *suggestive*. While *corrective feedback* mainly identified grammatical errors and conceptual incorrectness, *confirmatory feedback* included comments that reiterated the agreement between the assessor and the author. *Suggestive feedback,* in contrast, was the most cognitively demanding: it entails both diagnosis of misconceived knowledge and constructive suggestions for improving the quality of the written arguments. The second main category, *metacogntion-based feedback,* illustrated how the assessor reflected on their own work and would make improvements if they were to rewrite it. Last, *affection-based feedback* primarily consisted of encouraging and complimentary comments on the work being assessed.

Based on in-depth qualitative analysis, this categorization aligned with the typology that Topping (1998) proposed. More importantly, it shed light on how existing characterization of peer feedback should be extended given the diverse types of tasks. Constructing written arguments is a challenging task and thus rather cognitively demanding. Students who are new to this task may find themselves less prepared for either completing the task or commenting on other's work. As a result, affection-based feedback may be more prevalent in this context. However, affection-based feedback may not necessarily appear in other less challenging situations. Future research should explore how different types of task may yield variations in the categorization of peer feedback.

Table 2: Categorization of feedback participants provided in peer assessment

Main Category	Subcategory	Definition	Example
Cognition-based	Corrective	Focused on basic aspects such as the length and grammatical issues of the arguments	*"A couple of times you said 'change' when it was supposed to be 'changes'"*
	Confirmatory	Discussed agreement with the author in aspects such as conceptual understanding or personal beliefs	*"The information in the summary reveals a correct understanding of the concept"*
	Suggestive	Focused on the quality of the argument, such as evidence used, the strength of justification in the arguments, and so on; constructive suggestions were made for further improvement	*"You believe that development is in separate stages, but throughout your argument, I feel as if you got lost. For a strong argument try to give examples that support your claim"*
Metacognition-based		Self-reflective comments on others' work, often discussing how they would improve their own work	*"I never thought of using this example."*
Affection-based		Encouraging and/or complementary comments on others' work, usually focusing on its overall impression rather than its content	*"Great job!"* *"I really liked the way you organized the paragraphs."*

Research question 2

Students' written arguments were evaluated based on the rubric they were provided with. Considering the nature of this investigation and the limited sample size, the relationship between peer assessment and student learning of written argumentation was investigated qualitatively and three patterns were identified to illustrate the nature of this relationship. First, the feedback students provided was mostly affection-based during the first peer assessment, with few students using both affection-based and cognition-based feedback. More cognition-based and metacognition-based feedback emerged during the third and fourth peer assessments. Second, the more cognition-based feedback one received, the more likely they would later provide feedback with similar focus. For example, when a student received corrective comments on their grammar, they tended to also evaluate others' arguments in this aspect the next time. Last, changes in students' own arguments were observed to occur mostly when they had previously received or made metacognition-based comments during peer assessment.

This finding, while limited in its generalizability, implied the complex nature of peer assessment and how it may influence students' learning outcomes. It revealed a potential alternative to understand the mixed findings in the literature regarding the effectiveness peer assessment. As the types of feedback one may provide and receive vary largely, it is critical that future studies investigate this topic in more depth at a micro level. Such efforts will not only enrich our understanding of peer assessment but also provide implications for improving students' skills in self- and peer assessment.

Research question 3

Students' reflection journals were analyzed to obtain an understanding of their perceived experience in peer assessment. While it was a common concern among students that they would not be able to provide their peers with helpful feedback, most students valued the opportunities to read their peer's written work. At the same time, students mentioned several drawbacks of engaging in peer assessment. First, it was time-consuming as they needed to carefully read through the writing before providing any feedback, and without much previous experience, this process took them much longer than expected. Second, when there was inconsistence between their own understanding of a concept and that of the peer's, students felt lack of confidence to make a mark but also did not necessarily resort to others for clarification. Additionally, being aware of the quality of others' work may lead students to be less committed to completing their assignments with high quality. Students reported having trouble to devote the same levels of efforts to their own work after reading a peer's sloppy writing.

Students usually need to see the value and relevance of assessing their peers to make the most out of this experience (Hanrahan & Isaacs, 2001). The current findings indicated that when exposed to a relatively challenging task, such as writing a quality argument, students may find peer assessment valuable, yet overly difficult. Therefore, how to incorporate peer assessment so that students are more motivated and actively engaged remains to be further studied. Nonetheless, as shown in previous research, novices tend to view their peer's

evaluation more understandable and acceptable in comparison with experts' (Cho & MacArthur, 2010). Receiving peer feedback is more likely to lead one to revisit their work and make further revisions (e.g., Gielen, Peeters, Dochy, Onghena, & Struyven, 2010). Hence, in this study, students' perception of the value of peer assessment may also help to explain the observed progress in their learning of written argumentation.

Conclusions

The present study explored how engaging in peer assessment may influence students' learning of written argumentation. Our findings suggested that providing and receiving peer feedback may enhance the quality of the arguments students generate, but this effect varied depending on the type of the feedback. By exploring the potential benefits of peer assessment, this study adds to our understanding of how collaborative learning activities may facilitate students' performance in generating evidence-based arguments. At the same time, the discussion of student argumentation also extends the scope of previous research on peer assessment, as it proposes an alternative approach to evaluate the learning outcomes of peer assessment.

Given the nature of the course that served as the study context in this work, the sample size was relatively small and interpretation of the findings should be carried out with cautions. However, the in-depth qualitative analysis of multiple data sources in this study helped to gain a deep insight into how peer assessment may affect students' learning processes. The current findings invite further research to investigate the impact of peer assessment on students' argumentation skills. In all, this research proposes a potentially effective approach to facilitate student learning in written argumentation and constitutes first steps in enhancing under-represented students' academic performance and helping them succeed in college.

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Newcomer Integration in Online Knowledge Communities: Exploring the Role of Dialogic Textual Complexity

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Abstract: Using online knowledge communities (OKCs) as informal learning environments poses the question how likely these will integrate newcomers as peripheral participants. Previous research has identified surface characteristics of the OKC dialog as integrativity predictors. Yet, little is known about the role of dialogic textual complexity. This contribution proposes a comprehensive approach based on previously validated textual complexity indexes and applies it to predict OKC integrativity. The dialog analysis of $N = 14$ blogger communities with a total of 1937 participants identified three main components of textual complexity: dialog participation, structure and cohesion. From these, dialog cohesion was higher in integrative OKCs, thus significantly predicting OKC integrativity. This result adds to previous OKC research by uncovering the depth of OKC discourse. For educational practice, the study suggests a way of empowering learners by automatically assessing the integrativity of OKCs in which they may attempt to participate and access community knowledge.

Introduction

Learning in knowledge communities (KCs) is a significant topic of the Learning Sciences (Bereiter & Scardamalia, 2014), especially in the context of social web applications, that in recent decades dramatically extended the possibilities of communication and collaboration, giving birth to online KCs (OKCs). In this context, newcomer integration in KCs is a research topic of increasing importance (Eberle, Stegmann, & Fischer, 2014). In the relatively new domain of Learning Analytics, some attempts have been made to automatically monitor and predict newcomer integration in OKCs as a first step in an informal learning process (Nistor et al., 2015b). Such studies assume that community practice is reflected in, or even an organic component of, the community discourse (Wenger, 1998); consequently, newcomer integration in OKCs can be monitored and predicted by automated dialog analysis (Baker & Siemens, in press). Yet, little is known about the textual attributes of the OKC dialog, and specifically about its textual complexity. This contribution (1) proposes a comprehensive approach to textual complexity, and (2) applies this approach in the dialog analysis of blogger OKCs in order to (a) identify the ground dimensions of dialogic textual complexity and (b) predict how likely the OKCs generating this dialog will integrate newcomers. The results are expected to contribute to a deeper understanding of OKC discourse and practice, thus enabling the integration of OKCs in formal collaborative learning environments, and empowering learners by supporting more efficient knowledge sharing in OKCs (Nistor et al., 2015c).

Theoretical background

Dialogic textual complexity in knowledge communities

KC research (Bereiter & Scardamalia, 2014; Wenger, 1998) describes discourse as connecting community practice, participants, and their knowledge about the practice. As such, discourse appears to be the essence of experience-based knowledge construction and sharing in KCs, which comprises the interplay between participation and reification. While participating, KC members acquire experience and reify it, thus developing cultural artifacts. Artifacts, in turn, support participation at a higher level. KC discourse includes both processes. At the same time, KC discourse includes the negotiation of meaning and the collaborative construction of shared knowledge, thus supporting the transition from distributed to shared knowledge (Wenger, 1998). Regarding the KC dialog as the spoken dimension of discourse, from a linguistic perspective, the following dialog characteristics can be observed:

Initiation of, and participation in, the community dialog. KC members participating in the community practice and encountering various problems will initiate and participate in a dialog aimed at coordinating activities, negotiating meaning and constructing shared knowledge. As a measurable result, a number of words, utterances and discussion threads will be produced (Dascălu, 2014).

Dialog structure. Connecting practice and knowledge about practice requires at linguistic level a specific vocabulary. Therefore, the produced words and utterances will build upon discourse structures consisting of main notions and connectors of these notions, such as cue phrases, co-references, speech acts, adjacency pairs, and rhetorical schemas (Jurafsky & Martin, 2009).

Dialog cohesion. Carrying out community practice and collaboratively constructing knowledge over longer periods of time (Wenger, 1998) requires cohesive dialog. Both the threads of utterances produced around single moments of practice, and different dialogs emerging in time from the community practice will be cohesive. This implies local cohesion (i.e., the dialog will be cohesive in itself, as shown by the dialog structure dimension), as well as global cohesion (i.e., between discussion threads and dialogs within the community practice) (McNamara, Graesser, & Louwerse, 2012).

These three dimensions of the collaborative KC dialog were named here in the order of increasing *textual complexity*. Initiation of, and participation in, the community dialog is supposed to reflect the surface, dialog connectedness its structure, and dialog cohesion the depth of KC discourse.

The assessment of collaborative dialog appears to be a productive method of quantitative KC research. After several decades of qualitative research, quantitative methods become more visible in the empirical approaches to knowledge communities. In Learning Analytics, particularly in Discourse Analytics, methods including social network analysis, clustering, and factor analysis were applied to identify socio-cognitive structures and predict learning in technology-based environments (Baker & Siemens, in press). Assuming that community discourse is tightly connected with socio-cognitive structures, practice and learning (Wenger, 1998), Nistor et al. (2015c) use *ReaderBench,* an automated dialog analysis tool based on Bakhtin's (1981) dialogism and on the polyphonic model of discourse (Trăușan-Matu, 2010), to assess the quality of the collaborative text-based dialog in OKCs. These dimensions were correlated with participants' expertise and centrality in the KC (Nistor et al., 2015c). Yet, little has been done to quantitatively assess the textual complexity of the KC dialog and to explore its relationship with the KC structure and processes.

Assessing textual complexity

Every dialog must be understood by the individuals involved in it. Building on this basic assumption, several categories of complexity indexes have been developed and validated ranging from surface factors to more in-depth dialog characteristics such as syntax and semantics (Dascălu et al., 2013; 2015). Firstly, the *surface* category is based on statistics of individual analysis elements (words, phrases, paragraphs) derived from classic readability formulas, as well as Page's (1966) grading technique for automated scoring covering basic structure complexity (e.g., number of words, of commas, of sentences, word length, average number of syllables per word, or of words per sentence) and word/character entropy. Secondly, the *syntax* category changes the focus to statistics applied per different parts of speech (e.g., nouns, prepositions, pronouns), as well as the complexity of the parsing tree in terms of its maximum depth and its size of the parsing structure (Dascălu, 2014). Thirdly, the *semantics and discourse analysis* category is based on cohesion graphs (Dascălu, 2014), the strength of the links between different analysis elements (intra-contribution between sentences, inter-contributions to reflect a cohesive flow), as well as named entities identification and specific discourse connectives covering coordination, subordination, conditions, contrasts or sentence linking.

Methodology

Research questions

Given the comprehensive collection of indexes named above, it is still unclear which of these are representative for the notion of OKC dialog complexity and predictive of newcomer integration. Therefore, the following research questions are examined: (1) Which independent dimensions of textual complexity can be identified in the OKC dialog? (2) Which of these can predict newcomer integration?

Data collection

The analysis was conducted on the Internet, in blogger communities publicly available on the blogspot.com and wordpress.com platforms. In a prior study, the researchers had attempted to initiate discussions in several blog communities, observing that some communities were more open to dialog and more likely to integrate newcomers than others, consequently the former were regarded as integrative ($n = 3$), the latter as non-integrative ($n = 11$) OKCs. After these $N = 14$ blogger communities with a total of 1937 participants were chosen, the entire community discourse produced within a year (ending with the day of the intervention that should have initiated new conversation threads) was downloaded and automatically analyzed. No personal data of the participants were collected.

Data analysis

The textual complexity analysis tool provides a wide range of indexes out of which 89 dialog indexes were used: 18 *surface indexes* (e.g., average sentence length in characters, average number of commas per sentence, average number and standard deviation of words in sentence, word entropy), 25 *syntactic indexes* (e.g., average number of nouns/ pronouns/ prepositions/ adjectives/ adverbs/ verbs per sentence/ paragraph, average parsing tree depth,

average parsing tree size), and 46 *semantic indexes* (e.g., average number of named entities per paragraph, average number of connector type per paragraph, average paragraph/contribution score, average sentence-paragraph/inter-paragraph/intra-paragraph/paragraph adjacency/ transition cohesion in terms of Wu-Palmer, Latent Semantic Analysis and Latent Dirichlet Allocation semantic distances) (see overview in Dascălu, 2014). Because these were strongly correlated with each other, a main component analysis was performed to determine the independent dimensions of textual complexity. Afterwards, two subsamples of $n = 3$ integrative (with a total of 270 participants) and $n = 4$ non-integrative (460 participants) blogger OKCs with the same discussion topic (politics and economy) were chosen, and compared with respect to the main components of the textual complexity. Subsequently, a discriminant analysis was performed in order to assess the adequacy of the classification.

Findings

Principal component analysis
The 89 selected textual complexity indexes were reduced to three factors accounting for 91% of the total variance. Three dimensions resulted after eliminating 49 indexes with eigenvalues smaller than 1 and cross loadings over .4 on more than one factor, performing varimax rotation and saving the components according to the Anderson-Rubin method. Factor 1, interpreted as *Dialog Structure,* includes 28 factors, classified as discourse connectors (e.g., number of conjuncts per paragraph), syntactic indexes (e.g., number of verbs per paragraph), and indexes of basic structure and word diversity (e.g., number of words per paragraph). Factor 2, interpreted as *Dialog Cohesion,* includes 16 indexes, classified as local cohesion indexes (e.g., sentence-paragraph cohesion) and global cohesion indexes (e.g., inter-contribution and transition cohesion). Factor 3, interpreted as *Dialog Participation,* includes 6 indexes (e.g., number of initiated discussion threads).

Predicting newcomer integration
Dialog Cohesion was higher in integrative OKCs (z values $M = .21$, $SD = 1.11$) than in non-integrative OKCs ($M = -.02$, $SD = .88$), and the difference was statistically significant with $F(1, 728) = 9.924$, $p = .002$. Dialog Participation was also higher in integrative OKCs ($M = .11$, $SD = 2.49$) than in non-integrative OKCs ($M = -.07$, $SD = .47$), however this difference failed to reach statistical significance with $F(1, 728) = 2.219$, $p = .14$. Discourse Structure was roughly the same (.24-.25) in both subsamples. A discriminant analysis confirmed Dialog Cohesion as a significant predictor of OKC integrativity, with Wilks $\lambda = .987$, $p = .002$.

Discussion
Aiming to explore the role of dialogic textual complexity, and to predict how likely OKCs integrate newcomers, this study analyzed the dialog produced in blogger OKCs and identified three complexity dimensions: Dialog Participation, Dialog Structure, and Dialog Cohesion. These synthesize a large number of indexes from previous research literature describing textual complexity (Dascălu, 2014).

From these, the surface factor Dialog Participation was somewhat higher in integrative OKCs, which is in line with the differences reported by Nistor and colleagues (2015b). As a possible explanation, integrative OKCs are more open to dialog, and more active, more "talkative", which opens newcomers more opportunities to participate and access specific OKC knowledge (Eberle et al., 2014).

More interestingly, the Dialog Cohesion, the most in-depth complexity factor, was significantly higher in integrative than in non-integrative OKCs, thus predicting OKC integrativity. This result adds to previous OKC research, and suggests that integrativity may be an aspect of the previously established community discourse. Nistor et al. (2015a) measured dialog quality as the percentage of social knowledge building per utterance, a participation centered, thus a surface indicator in terms of textual complexity. This study goes beyond the surface and uncovers the depth of OKC dialog. In non-integrative OKCs, the socio-cognitive component (mainly knowledge construction and sharing between active members) may dominate the community discourse, while in integrative OKCs this component may be balanced with the social component (member identity negotiation and development, new member recruitment, monitoring and training – Eberle et al., 2014). Therefore, the more balanced and complex nature of practice in integrative OKCs may result in a more complex discourse and, respectively, dialog.

Conclusions
For the practice of computer-supported collaborative learning, this study suggests a way of empowering informal learners who attempt to access OKC knowledge. Automated analysis tools can indicate their chances of success with a particular OKC, and thus enable them to be more efficient in their search of a responsive community. Thus, OKCs can also be integrated in formal learning environments (Nistor et al., 2015c).

For research and development in the Learning Sciences, this study contributes to the relatively new domain of Learning Analytics with more accurate procedures and tools for monitoring and predicting learning behaviors (Baker & Siemens, in press) and, more generally, with a deeper understanding of OKC discourse and practice. Further research will propose and evaluate formal learning scenarios based on OKC integration and participation.

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Acknowledgments

Is Small Group Collaboration Beneficial in Large Scale Online Courses? An Investigation of Factors Influencing Satisfaction and Performance in GroupMOOCs

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Abstract: The paper analyzes students' experience within a large scale e-learning course in a higher education setting. During the course students worked on successive assignments individually or in groups of three students in an alternating fashion. Captured data include students' platform behavior (login, resource accesses, e.g., literature access, video access, active days, completed quizzes, resource coverage), students' final course grade as well as learning preferences, intrinsic motivation and satisfaction assessed via questionnaire. Results reveal that of those variables the satisfaction with the collaborative tasks is merely related to students' overall course evaluation.

Keywords: MOOC, e-learning, collaboration

Introduction

Massive open online courses (MOOCs) support a "large-scale interactive participation" (Conole, 2013, p. 6) and have received more and more attention from the academic community (Khalil & Ebner, 2014). These online courses attempt to create interactivity between the participants by means of offering discussion forums (Conole, 2013) and increasingly also by incorporating collaborative tasks which are seen as an opportunity for participants to engage with the course and the learning material. Further, it was demonstrated that interactivity, (e.g., discussion forums) is related to higher academic performance (Anderson, Huttenlocher, Kleinberg, & Lescovec, 2014). In MOOCs collaboration between students typically takes place in a plenary discussion forum. Though these discussion forums allow interaction, only a small proportion of students take advantage of it (Kizilcec, Schneider, Cohen, & McFarland, 2014). A subcategory of MOOCs that makes particular use of this aspect is groupMOOCs "where the focus is on collaboration in small groups" (Conole, 2013, p. 9). Small-group learning tasks can be beneficial as they can support task processing and problem solving (Ku, Tseng, & Akarasriworn, 2013). Additionally, it has been shown in several studies that collaborative tasks give rise to higher levels of satisfaction of students' learning process (Bolinger, 2004), and that students are more satisfied with their online course if they perceived higher levels of collaborative learning (So & Brush, 2008). This can be seen as especially important because satisfaction increases students' motivation to participate (Bolinger, 2004). However, there are certainly also problems with regard to group work. Roberts and McInnerney (2007) summarized the seven most common problems and highlighted students' general antipathy towards group work. Well-known phenomena in group work include problems like social loafing and free-riding (e.g., Piezon & Donaldson, 2005).

The goal of the study was to determine the possible influence of group tasks and individual task-related satisfaction on overall course evaluation and performance. In order to understand which aspects are related to students' general satisfaction with the course as well as to their general performance in the course we first conducted an explorative analysis. The goal was to analyze how students' learning preferences (cooperative, individualistic, competitive), prior intrinsic motivation, as well as specific behavior during the course (literature access, active days, video access, completed quizzes and resource coverage) were related to individually perceived satisfaction and overall performance as assessed via the final course grade.

On the basis of these prior considerations, we formulated the following research questions:

RQ1: Are intrinsic motivation, learning preferences and behavior on the online platform (literature access, active days, video access, completed quizzes and resource coverage) related to course satisfaction?

RQ2: Are intrinsic motivation, learning preferences and behavior on the online platform related to the final course grade?

In accordance with the assumption that a beneficial perception of collaboration and satisfaction with the course are correlated positively we derived the following hypothesis:

H1: The satisfaction with a collaborative task is positively related to students' overall course satisfaction.

As stated by Anderson and colleges (2014) interactivity (e.g., discussion forums) is related to higher academic performance and collaboration can foster academic engagement (Wentzel & Watkins, 2002). Therefore, we hypothesized that:

H2: The satisfaction with a collaborative task is related to students' final course grade.

Additionally, we strived to understand whether the learning preferences with regard to collaboration affect the satisfaction with the collaborative task as well as moderate the relation of satisfaction with the group task and overall course evaluation:

H3: Learning preference for collaborative learning is positively related to the satisfaction with the collaborative task.

H4: The individual learning preference for collaborative learning moderates the relation of satisfaction with the group task and overall course evaluation.

Methods

This study was conducted during an online seminar at the University of Duisburg-Essen and Ruhr-University Bochum over a period of one semester. Students of different study programs (and faculties) participated in this course. We chose Moodle as our platform, which is commonly used by universities and designed to support teaching as well as learning. This platform delivers a large number of learner-centric tools and collaborative learning environments. Furthermore, to facilitate typical MOOC features, our Moodle platform was customized by adaptation and configuration of a collection of existing tools for individual and collaborative learning.

Before participation in the course students were asked to provide informed consent to the usage of their behavioral data logged by the platform for research purposes (157 or 90.2% students agreed). The students' log files contained timestamped information about the login, resource accesses, e.g., literature access, video access, completed quizzes, and participation in questionnaires. The recorded actions of each type were counted for each week of the course. Further measures i.e., active days and resource coverage (subset of course material that a student has actually used) in the corresponding week were calculated. Based on the personal platform ID of every single student, it was possible to assign log files to surveys thereby providing the opportunity to analyze relations between self-reported data and process measures.

In a time period from week 6 to 10 students completed two collaborative and two individual tasks. In both tasks students should submit a text regarding a case scenario that was based on a weekly topic regarding computer-mediated communication (e.g., social interdependence theory). In the collaborative task students had to discuss theoretical aspects, their ideas, and their final submission in a forum with 2-3 fellow students whereas students of the individual task had no opportunity to discuss their ideas. Subjective satisfaction with the type of the task was surveyed, however, only data from two weeks (9 and 10) could be used due to a database error.

Students participated in several online questionnaires. Students were asked about the completed task and whether they preferred to complete the task collaboratively or individually. The questionnaire consisted of 12 ad-hoc items on a 7-point Likert scale (ranging from 1 = strongly disagree to 7 = strongly agree). With an exploratory factor analysis using Horn procedure (Fabrigar, Wegener, MacCallum, & Strahan, 1999) two factors were determined. Factor 1 consisted of 9 items indicating *liking group work* (e.g., "I liked to work on this task with others") with an internal consistency of .93 (Cronbach's α). Factor 2 consisted of 3 items indicating *exhaustion* (e.g., "Working with others was exhausting"; Cronbach's α = .74).

We assessed intrinsic motivation of the students at the beginning of the course using 5 items from the academic self-regulation questionnaire (SRQ-A) by Müller, Hanfstingl, and Andreitz (2007) ranging from 1 = strongly disagree to 5 = strongly agree (e.g., "I am learning in this online lecture because I find it fun"; Cronbach's α = .88).

Further, we employed Johnson and Norem-Hebeisen's (1979) measure of cooperative (7 items, e.g., "I like to help other students learn"; Cronbach's α = .86), competitive (8 items, e.g., "I like to do better work than

other students"; Cronbach's α = .91), and individualistic attitudes (7 items, e.g., "I don't like working with other students"; Cronbach's α = .72), using a six-point Likert scale (ranging from 1 = strongly disagree to 6 = strongly agree).

The satisfaction with the online course was measured with a single item ("I liked the online course"), and the final grade of the online course was assessed.

Findings

To investigate RQ1, we conducted a linear regression ($n = 31$). Results showed no statistically significant relation between intrinsic motivation, the learning preferences as well as the online behavior on the platform (literature access, active days, video access, completed quizzes and resource coverage) and course satisfaction, $F(11,19) = 1.26$, $p = .32$, $R^2 = .42$.

A similar analysis strategy was chosen to investigate RQ2 ($n = 49$). Results revealed no statistically significant relation between intrinsic motivation, learning preferences, online behavior on the platform and course satisfaction, $F(11,37) = 60$, $p = .82$, $R^2 = .15$.

To test whether the satisfaction with collaborative tasks is related to the general satisfaction with the online course, we conducted a linear regression using the two factors *liking group work* and *exhaustion* as predictors and the single item "I liked the online course" as the outcome (H1). Results revealed a statistically significant relationship between the two factors ($n = 29$; factor 1: $M = 3.57$, $SD = 1.58$; factor 2: $M = 4.86$, $SD = 1.40$) and course satisfaction, $F(2,26) = 5.47$, $p < .01$, $R^2 = .30$. Furthermore, a linear regression was conducted ($n = 37$) to test the relationship between satisfaction with the collaborative tasks and the final grade (H2). Results revealed no statistically significant influence, $F(2,34) = .31$, $p = .74$, $R^2 = .02$. Therefore, hypothesis H1 is supported while hypothesis H2 is not supported.

To test H3, we conducted a linear regression ($n = 33$) using learning preference *cooperative* as predictor and satisfaction with the collaborative task as outcome variable. Results showed no statistically significant relationship, $F(1,31) = 3.06$, $p = .09$, $R^2 = .09$.

In order to test H4, we conducted a moderation analysis ($n = 23$) using the PROCESS macro for SPSS (Preacher & Hayes, 2008) with course satisfaction as predictor, factor 1 *liking group work* as outcome and learning preference *cooperative* as moderator. Results of the overall model showed no statistically significant relationship, $F(3,19) = 2.18$, $p = .12$, $R^2 = .32$. Results also revealed that factor 1 is a statistically significant predictor of course satisfaction ($b = .25$, $t(19) = 2.49$, $p = .02$). The interaction of factor 1 and learning preferences cooperative revealed no statistically significant relationship ($b = -.17$, $t(19) = -.59$, $p = .56$). Therefore, no moderating effect of learning preferences on the interaction between factor 1 *liking group work* and course satisfaction was found.

Conclusions and implications

Our findings revealed no statistically significant relationship between intrinsic motivation, learning preferences, online behavior on the platform and course satisfaction or final course grade. Therefore, neither students' traits with regard to cooperative learning, nor their prior motivation, nor what they actually did was related to their overall satisfaction with the course or their performance. While this might be due to the fact that there was no sufficient variance with regard to intrinsic motivation and learning preference, the fact that behavior was not related to learning results is more astonishing, especially as this was demonstrated in prior studies (Ziebarth et al., 2015). We suggest that these findings need to be considered carefully, and that direct and conceptual replications are warranted before definitive conclusions from such counterintuitive null findings should be drawn.

While the satisfaction with a collaborative task was not related to students' final course grade, our analyses revealed that there was a statistically significant relationship between collaborative task satisfaction and course satisfaction. Therefore, the satisfaction with a single collaborative task in merely one of the altogether 14 weeks is related to the general evaluation of the online course. This corroborates prior research that found collaborative tasks give rise to higher levels of satisfaction of students' learning process (e.g., Bolinger, 2004). As the present study was correlational in nature, it paves the way for research employing experimental procedures to elaborate the causal mechanisms of this relationship (e.g., investigating whether the manipulation of specific factors that contribute to or are detrimental to collaborative task satisfaction also affect course satisfaction).

This study has several limitations that should be acknowledged. Since the concept of the course was new, there were several problems, e.g., with regard to groups assignments, which did not go unnoticed by the students and might have contributed to a rather low course satisfaction. Also, not all students who participated in the course took part in the survey. Due to a database error not all weeks in which students had to work in groups could be considered. In sum, the statistical power for our analyses was quite low, therefore the many statistically nonsignificant results have to be interpreted with due care.

Nevertheless, we believe that our field study provides some relevant insight on a number of factors previously identified as being potentially related to groupMOOCs, and could be built upon in future research on (collaborative) learning in large scale online courses. Our study highlights that group tasks are not the panacea to high course satisfaction, but that they need to be planned and supervised carefully to make a meaningful contribution to learning outcomes.

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Acknowledgments

Embodied Search Processes in Creative Problem Solving: How Do People Learn in Makerspaces?

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Abstract: In creative problem solving, an essential component is the divergent idea generation phase before deciding on a plan of action for convergent, relatively well structured problem solving. In makerspaces and other sites where problems are posed in physical form, the material affordances of the objects and their spatial configurations can aid or hinder the search through problem space for possible solutions. In this study, we present the preliminary results of a study involving six pairs of grade eight students involved in a school makerspace context. Given sixteen littleBits modules housed in a small toolbox, along with some light construction materials, students were tasked to produce a prototype of a device that could attract teachers' attention during class work sessions. The material actions that students made in early exploration of project ideas were correlated to the creative outcomes of their project.

Keywords: embodied cognition, creative cognition, makerspaces, student learning, design

Introduction

Makerspaces are quickly gaining prominence as sites for creative problem solving, and the acquisition of STEM skills and dispositions. However, while studies have shown makerspaces to successfully engage students in such learning tasks, substantially less research has taken place to discern the curriculum and learning mechanisms involved in tinkering and making. For instance, constructionism supposes that learning is inherent whenever students have the opportunity to 'mess around' with things or complex systems in an intellectually engaged manner. While this may be the case, we know a lot less about the constituent processes that inform this form of learning. More generally speaking, beyond phenomenological analyses of learning by doing, and assertions of the primacy of tacit knowledge (Polanyi,2009), and the anti-intellectual philosophical position taken by Ryle (1945) and more recent contemporary revisions (Brock, 2015), we really have little knowledge of the mechanisms by which we learn when we 'learn by doing'. Coupled with the typical makerspace activity of tinkering, which noted design leaders (Kelley & Kelley, 2013) have dubbed 'thinking with your hands', the question arises as to the mechanisms through which tinkering and making are educationally beneficial activities, and what may be the specific benefits that may be derived from tinkering and making, beyond the much vaunted benefits of engagement and arousing interest in STEM.

Review

Based on social constructivist pedagogical principles, and sociology of science studies that repudiate the typical classroom practices of science instruction that privileges abstractions, makerspaces have been a recent phenomenon that has begun to receive attention of the scholarly community. Predominantly, researchers have looked at the increased engagement, creative output, and STEM learning gains (see, e.g. edited volume by Honey & Kanter, 2013; Bevan, Gutwill, Petrich, & Wilkinson, 2014), but considerably less attention has been paid to the particular cognitive mechanisms through which makerspaces are educationally beneficial. This consideration extends beyond research in the specific context of makerspaces, to also include general practices of 'learning by doing', and the insight and tacit knowledge generated.

In creativity research, a major recent change has been to consider not merely the divergent generation of ideas, but also the convergent selection and realisation of a particular creative idea. This is especially in light of the currently accepted dual level definition of what creativity constitutes—an idea of novelty, and of utility, as novel ideas may be generated by random processes but may not be useful. In parallel to this, very recent work (Goel 2014, Reed 2015) have identified particular cognitive tasks that appear to be congruent to the two major phases of what have been termed the geneplore model for creativity (Fink, Ward, Smith, 1994). Essentially, if the processes in creativity can be thought of as consisting of a divergent idea *gene*ration stage, followed or interspersed by a convergent ex*plor*ation stage, the cognitive tasks associated with these stages are respectively ill-structured and well-structured problem solving.

Divergent idea generation, especially when solving design problems, have similar characteristics to ill structured problem solving. With design problems, Goel and Pirolli (1992) point out that, among other things, design problems are: often large and complex; do not have right or wrong answers, only better or worse ones;

have many contingent interactions between components; and, components of design problems—start, goal, and intermediate states—are incompletely specified. Certainly, this is not to claim that design is solely made up of divergent, ill structured tasks; design solutions need to eventually be created, and the divergent possibilities need to collapse into a concrete instantiation of a design. Nonetheless, ill structured problem solving remains a central part of design problem solving, and the search for possible solutions within a problem space is an important task that designers need to grapple with. As Hills *et al*. (2015) point out, the process of search is a ubiquitous requirement for life, from animal behaviour, to individual and social human behaviour, to also include abstract, internal processes. The core problematic appears to be a trade-off between exploiting known opportunities and exploring for better opportunities elsewhere: whereas exploring elsewhere could reveal richer sources of food, information, or innovative solutions to problems, this is often done at the expense of being able to exploit whatever resources one has at hand.

In this regard then, we consider the design problem solving task from the perspective of search, and study the ways in which students assigned a problem make use of material resources in an embodied manner to search for potential solutions. We make use of the perspective of embodied cognition to make sense of their actions and gestures. With embodied cognition, philosophers and researchers posit the hypothesis of cognitive externalisation, that is, that the world is its own best representation (Clark, 2008; Noe, 2009); and that certain actions need to be considered as *epistemic* if, as a consequence of the action, we obtain more reliable information about reality (Kirsh & Maglio, 1994). Specifically, considering the insight and divergent idea generation phase of design, we proposed that certain actions and ways of ordering the immediate environment around oneself can serve a cognitive function to provide insight into problems, just as trajector-based cultural practices (Hutchins, 2013) reduce the cognitive load for embedding meaning by seeing the world in a particular way. We therefore set out to characterise actions taken by students as they 'tinkered' their way to solving a design prompt.

Methods

We report here on a study conducted with six pairs of students assigned to a rapid design problem solving task. The design prompt was "Within an hour, design and make a device that could signal your teacher's attention during class group work session". The students were offered a small plastic toolbox, filled with 14 pieces of littleBits, two A3 sized pieces of foam core cardboard, 10 wooden skewers, a box cutter, a steel rule, a cutting mat, a hot melt glue gun, and some paper and pencil to sketch their draft ideas on. littleBits is a system of magnetically connectable electronics components which allows students to quickly snap together electrical and electronic circuits with little consideration as to the polarity and other electrical constraints. They come in color coded modules, with the different colors representing its function as either: power supply, power/signal wire, signal input, and device output. The magnets and physical module interface ensure power, signal, and ground connections were correctly connected. Signal inputs came in the form of human adjustable modules (buttons, potentiometers), to other sensors which could receive input from physical events. Output modules included motors, lights, and speakers. Some typical modules are shown below:
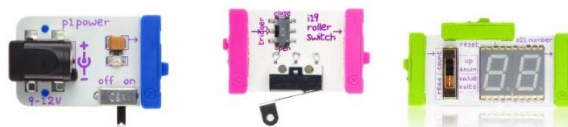
Figure 1. littleBits modules: from left to right: power, input, output.

As can be imagined, the combinatorial possibilities for connecting different modules offer a fairly wide solution space from which candidate designs may derive from. Add to this the flexibility of cutting and joining the other materials, the search space offered to students was wide indeed. As a means to constrain the design outcomes between our participants, we chose a subset of all available modules, using modules that students had familiarity with; we offered student pairs modules as shown in Table 1.

While we initially considered a stimulated recall activity as a means to get single participants to recount their intentions as they proceeded in the design task, we eventually decided to get students in pairs so that their talk events in handling the mutual coordination of design intention could be made explicit. The task was briefly explained to the students and 2 volunteers were recruited per class at each available session. Student talk and action was recorded by a pair of cameras, one in front, and another behind and above the shoulders, so that there were no blind spots. Students were instructed to spend the first half hour planning their design solution, and the next half hour implementing it. Because we were actually interested in the role tinkering played in their design problem solving approach, we did not restrict their planning phase activity, and in fact suggested that they could 'play around' with the materials as they liked.

Table 1: list of littleBits modules provided for teams

Power	Input	Output	Wire
Power (x2)	Slide dimmer	DC motor (x2)	Fork wires (x2)
9V battery (x2)	Light sensor	Servo motor	
	Button	Buzzer	
	Pressure sensor	Long LED	
	Pulse generator		

Students were grade eight students in an independent boy's school in Singapore. These students were of above average academic ability, and had been participants in an art course which the teacher had deliberately made use of makerspace pedagogical principles. Video data were analyzed using Transana 3.0. A coding scheme for activity segments was developed and validated through consultation with colleagues. Through joint viewing sessions, pertinent episodes were identified where phenomena of interest were discussed and competitive theory generation was used to justify an explanation that fit the observations.

Findings

We developed a simple three level coding scheme to distinguish between low, medium, and high levels of creative outcome via a technique resembling the consensual assessment technique (Amabile, 1982). Briefly, a low level indicated designs which were simple circuit-only, with no utilization of other materials provided. A medium level was indicated by some usage of materials in conjunction with the electronic circuits, or a complex circuit-only design. A high level was indicated by an extensive use of materials in combination with a complex circuit. A summary of the six design outcomes are as follows:

Table 2. Summary of design outcomes for six pairs of students

Group	Intended design description	Rating/Comment
1	Two LEDs connected in parallel, one on teacher's table, and another on students' desk. When button switch is pressed by student, both LEDs will light up, teacher will then look around the class for a lit box to indicate which student needed assistance.	Medium. Some intelligent use of materials in combination with circuits but design is not practical
2	In parallel, three circuits: one to light up a LED, one to a pulsed signal to cause a buzzer to ring intermittently, and a final one to cause a white board to rotate to attract attention. Activated by a button, all three circuits will turn on simultaneously.	Medium-high*. Fairly complicated circuit with the highest number of modules used. Material usage quite innovative
3.	Cockpit/dashboard style display to be mounted on a wall or on teacher's desk to indicate which team(s) needed help.	Medium. Some use of material, but circuit was straightforward.
4.	In parallel, three circuits: one servo motor circuit. Second circuit connects to LEDs, and is mechanically supported on the servo motor so that LEDs physically oscillate. Third circuit activates a buzzer. Servo motor is always on, but LED and buzzer can be selectively switched.	Medium-high*. Complicated circuit, but no materials were used.
5.	Single circuit with a slide dimmer activating a buzzer. No significant deployment of material resources.	Low*. Upon unusual prompting, student pair decided to append an LED extension.
6.	In parallel, three circuits: one buzzer, one servo motor, one LED. Single switch activates all three circuits.	Medium. Circuit is of medium complexity, but material usage is minimal and not well implemented.

We developed a coding scheme to describe participant talk and action. Due to limited space, we describe a limited selection. Of action codes, we found students 'tinkering'; exploring material possibilities for goodness of fit to design intent. Due to the availability of speech data, we were able to infer students' intention. The directions of fit could be 'top down', or 'bottom up', referring to, respectively, trying to get materials to accommodate a design plan, and manipulating materials to explore potential with no apparent design plan.

Most of the groups did not have much by way of a systematic means of exploring the circuit resources available to them. In all cases, the time spent in bottom up tinkering exceeded top down tinkering. While some groups did begin by brainstorming means by which they could obtain teachers' attention, there seemed to be a distinct lack of intention in their solution attempt. For groups 1 and 3, littleBits modules had been inadvertently

laid out on their desks in a disordered manner. These groups did not further sort the modules, but instead only picked modules that they were familiar with (i.e., exploiting known resources), and left the rest on the desk.

Of note would be the contrast shown between the two higher performing groups and the low performing group. As to be expected, these two higher performing groups spent the most time exploring. Both groups 2 and 4 spent the time to get to know the circuit affordances of each of the parts, making use of the toolbox as a means to distinguish between parts that they had experimented with, and parts they had not. The systematicity in the exploration of groups 2 and 4 was displayed by sequentially connecting modules taken from the box, understanding its function, and then making mental notes (as they discussed) of what they could do with each module. When done, they would put aside useful modules distinct from modules that they did not find useful. In contrast, group 5's exploration, besides being short in duration, tended to repeat actions on modules. We could not infer that they had any order in the arrangement of modules (e.g. used/unusued), and they spent quite some time in unproductive tinkering (e.g. mechanically tapping a module not connected to power, or sliding the variable resistor faster than an effect could be observed). We did not detect any group with a deliberately explicated exploration strategy that made use of material resources as a means to reduce cognitive complexity, e.g. laying out all pieces according to color, and deciding on a strategy to sample modules. However, we cannot discount the possibility of internally organized designations of useful piles distinct from useless ones, as we did not interview students for their use of organizing routines.

Limitations, conclusions, and implications

This is a preliminary analysis presented for comments to the community; work is currently still in progress. A limitation of the data thus presented may be lack of diversity of participants. An effort currently underway is to compare the actions taken by experts provided the identical task. It appears that the top down/bottom up tinkering distinction corresponds loosely to the explore/exploit pair in search. In seeking creative solutions to design problems, it may be necessary to spend a balanced (not necessarily equal) amount of time in top down and bottom up tinkering modes. This finding presents a possible route for subsequent interventions—that learners need to distinguish between tinkering modes, to develop deliberately metacognitive strategies for the generation of creative solutions.

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Acknowledgments

Comparing Students' Solutions When Learning Collaboratively or Individually Within Productive Failure

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Abstract: In this article we focus on evaluating student solutions generated during the initial problem-solving phase of a Productive Failure study, where problem solving precedes instruction. In particular, we investigated whether collaboratively learning students came up with more solution ideas and generated qualitatively better solutions than individually learning students. Although descriptively the collaboratively learning students outperformed individually learning students with regard to both the quantity of solution ideas and the quality of solutions, we were unable to establish statistically significant differences. Moreover, we did not find correlations between students' solutions and their learning outcome. Possible reasons for the missing link are discussed. The analyses reported in this paper are based on yet unpublished data from a study by Mazziotti, Loibl & Rummel (2015).

Keywords: students' solutions, collaborative learning, Productive Failure

Introduction

Instructional approaches that comprise self-determined problem-solving prior to instruction often include small-group collaboration during problem solving. In the Productive Failure approach (PF, e.g., Kapur, 2012), for example, students first try to collaboratively solve a yet unknown problem (usually generating incomplete or erroneous solution approaches) and then receive explicit instruction building on their prior solution attempts. In order to shed more light on the role of small group collaboration for the effectiveness of PF Mazziotti, Loibl and Rummel (2015) conducted a 2x2 quasi-experimental study with the factors social form of learning (collaborative vs. individual) and timing of instruction (i.e., problem-solving prior to instruction, or PF vs. problem-solving after instruction, or Direct Instruction). We expected higher benefits from collaborative learning compared to individual learning (within PF) on students' conceptual knowledge acquisition because mutual collaborative explanations about students' problem-solving ideas trigger elaborative processes which in turn support students' conceptual knowledge acquisition (Teasley, 1995). However, in our previous study, individual students acquired descriptively more conceptual knowledge than their collaborative counterparts. Also when looking only at the students from the two PF-conditions, again, the individually learning students descriptively outperformed their collaborative counterparts.

In order to further unpack the role of collaboration within PF, we re-analyze the data from the Mazziotti et al. (2015) study. Our aim is to, go beyond investigating students' conceptual knowledge at the end of the intervention by analyzing students' solutions generated *during* the initial phase of PF. In line with previous research on PF, we investigate the quantity and quality of students' solutions and are thus able to make further comparisons between collaboratively and individually learning PF students. Investigating students' solutions is of particular interest as some previous PF-studies (e.g., Kapur, 2012) showed a positive link between the quantity and the quality of students' solutions and their learning outcome. For example, Wiedmann and colleagues (2012) showed that the number of different solutions as well as the number of high quality solutions were positively linked to students' learning outcomes.

Because in the collaborative problem-solving phase of PF, students are not only able to mutually explain their solutions but also to iteratively improve them by discussion, we hypothesize that within PF, collaboratively learning students generate qualitatively better solutions than their individual counterparts. Moreover, the collaboration may stimulate the solution generation, so we further hypothesize that collaboratively learning students come up with more solution ideas than their individual counterparts (as they can only rely on themselves). In line with previous research on PF, we further investigate whether there is a positive link between the quality and quantity of solutions on the one hand and their learning outcome on the other hand.

Methods

In order to investigate our hypothesis, we report unpublished data from the aforementioned study conducted by Mazziotti and colleagues (2015) by analyzing and comparing students' solutions.

Study design

In the aforementioned 2x2 quasi-experimental study (N= 228 fifth graders; Mazziotti et al., 2015), we varied the factors social form of learning (collaborative vs. individual) and timing of instruction (problem-solving prior to instruction, or PF vs. problem-solving after instruction, or DI), resulting in four experimental conditions (PF-Coll: N= 74 = 34 complete dyads, PF-Ind: N= 49, DI-Coll: N= 57 and DI-Ind: N=48). The experimental procedure comprised a problem-solving phase (either in dyads or individually) and an instruction phase (designed as a whole class lecture). While in both PF-conditions students first tried to collaboratively or individually solve a problem and then received instruction, in both DI-conditions students first received instruction and then tried to collaboratively or individually solve a problem. As the DI-conditions are beyond the scope of this paper, we here concentrate on a more detailed description of the PF conditions.

In the problem-solving phase (of the PF-conditions), students were engaged in solving a typical PF problem which is, in line with the PF design requirements (cf. Kapur & Bielacycz, 2012), a complex problem about equivalent fractions (see Figure 1). At the beginning of grade 5 students have not yet been formally introduced to equivalence of fractions and only have an initial understanding of fractions, so this problem was quite challenging for students and was not meant to be solvable by the students in the initial problem-solving phase. To further ensure complexity, our problem implied three (instead of one) problem-solving steps (which were not marked as such for the students; see Figure 1). By calculating a solution, applying logical reasoning, making use of a graphical representation (i.e. circle) or drawing various solution ideas, students were able to find multiple different solution paths (cf. design requirement Kapur & Bielaczyc, 2012, Mazziotti et al. 2015). During the instruction phase, the instructor built upon typical student solutions by comparing and contrasting them with the canonical solution (cf. Loibl & Rummel, 2014).
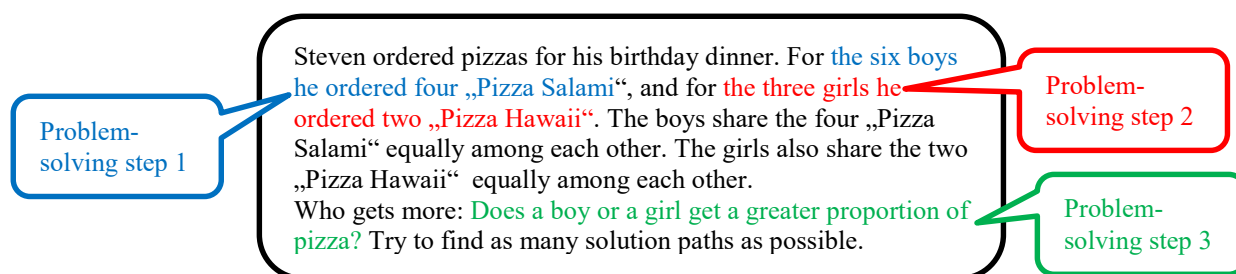
Figure 1: The equivalent fraction problem for the problem-solving phase of PF.

Overall, the study took place in three mathematics lessons (3x 45 minutes) and followed this procedure: In the mathematics lesson preceding the study, students were asked to fill out a pretest (10-15 minutes) that assessed students' mathematical prerequisites regarding fractions equivalence. The problem-solving phase took 30 minutes including 15 minutes introduction. The instruction phase took 45 minutes. All students had 45 minutes time to answer the posttest that assessed student's knowledge of equivalent fractions with open text-based items (6 items, some with multiple subtasks; a maximum of 17 points could be reached).

Quality and quantity of solutions

In order to investigate whether collaboratively learning students generated more and qualitatively better solutions compared to individually learning students, we analyzed the quality and quantity of students' solution solutions (cf. Kapur, 2012, Wiedmann et al., 2012). Naturally, quality and quantity are closely linked to the to-be-solved problem (see Figure 1).

For *solution quality*, we rated how well students divided the pizzas for boys and girls (cf. problem-solving steps 1 and 2), and how they compared the two proportions (cf. problem-solving step 3). Table 1 illustrates how many credits students could receive for each problem-solving step. In sum, assessing the quality of all problem-solving steps (dividing by number of boys, dividing by number of girls, comparing) leads to a maximum possible score of 9. As unit of analysis we used a single solution, that is, students' attempt to engage in all three problem-solving steps before restarting a new solution by engaging again in problem-solving step 1. Because 76% of the students across both conditions generated only one solution (i.e. attempt to solve *all three* problem-solving steps), we only rated the quality of this first solution.

To determine the *quantity of solution* we did not focus on the entire solution as unit of analysis (i.e., students attempt to engage in all three problem-solving steps), but used a more fine-grained approach in determining the quantity of *solution ideas* per problem-solving step. This was more appropriate for our target group because coming up with a new idea for a *single* problem-solving step rather than coming up with three

completely new ideas for all three problem-solving steps (i.e., a complete solution) is already challenging and therefore not highly likely (cf. 76% of all students generated only a first solution). In particular, Ruwisch highlights that young students have difficulties to desist from an idea and to re-orientate towards a new one (Ruwisch, 1999). As a coding example, drawing the four pizza Salami and dividing them for the six boys into halves was coded as one solution idea for problem-solving step 1, and drawing and dividing the four pizza Salami for the six boys into quarters as an alternative way was coded as another solution idea for problem-solving step 1. We summarized the number of solution ideas across all problem-solving steps into one sum score.

Table 1. Rating of the quality of students' solutions per each problem-solving step

Problem-solving step	Rating
Problem-solving steps 1& 2: Dividing the pizza for boys and girls	Dividing equally, fairly and without a remainder (e.g., into sixths, thirds, twelfths). (1 point for trying to divide + 1 point for dividing equally + 1 point for dividing without leaving a remainder = 3 points)
	Diving equally but unfairly (e.g., halves, quarters, fifths). (1 point for trying to divide + 1 point for dividing equally = 2 points)
	Avoidance strategies: Stating that some children are not hungry, or ordering more pizza so that children get whole pizzas. (1 point for trying to divide whole pizzas amongst the children = 1 point)
	Not trying to divide (0 points).
Problem-solving step 3: Comparing two proportions of pizza	Both pizzas are divided into the same amount of pieces (e.g., both pizza Salami and pizza Hawaii are divided into twelfths). Students can thus "prove" that each boy and girl receives the same proportion of pizza. (1 point for trying to compare + 1 point for comparing the equal amounts of pieces + 1 point for reaching the correct conclusion that each child receives the same number of pieces = 3 points)
	The two pizzas are divided into different numbers of pieces (e.g., pizza Salami into thirds and pizza Hawaii into twelfths). Due to a superficial comparison, students conclude correctly that each boy and girl receives the same proportion of pizza. (1 point for trying to compare + 1 point for reaching the correct conclusion that each child receives the same number of pieces = 2 points)
	The two pizzas are divided into different numbers of pieces (e.g., pizza Salami into thirds and pizza Hawaii into eights). Due to a superficial comparison, students conclude incorrectly that either a boy or a girl receives a smaller or greater proportion. (1 point for trying to compare = 1 point)
	Not trying to compare (0 points).

Two coders were trained to assess the quality of students' first solution and the quantity of students' solution ideas. To determine interrater reliability for the quantity of solution ideas, the raters both coded 43% of the paper-based data (i.e. PF-Coll and PF-Ind condition) and reached satisfactory interrater reliability (quantity of solution ideas κ = .65). To determine inter-rater agreement for the quality of the first solution, they both rated a subset of 20% of students' first solution. Agreement was high ($ICC_{absolute}$= .79; 95%-CI [.53; .92]). Disagreements were resolved by discussion.

Results and discussion

To test whether collaboratively learning students or individually learning students generated a higher quantity of solution ideas and a higher quality of the first solution, we calculated two univariate ANOVAs with the factor condition (PF-Coll vs. PF-Ind) and either quantity of solution ideas or quality of the first solution as the dependent variable. Table 2 shows means and standard deviations of both PF-conditions. Descriptively, the collaboratively learning students outperformed individually learning students with regard to both quality of their solution ($F[1,81]$ =2.178, p=.144) and the quantity of students' solution ideas ($F[1,81]$=0.949, p=.333), but the differences were not statistically significant.

In line with previous PF-studies, we calculated correlations between students' learning outcomes and their solutions. There was no significant correlation between students' learning outcome and the quality of students' solution ($r(117)$ =-.011, p=.902), or the quantity of students' solution ideas ($r(117)$=.081, p=.385). Looking at each PF-condition separately, we did not find significant correlations between students' learning outcome and the quality of their solution (PF-Coll: $r(68)$=.084, p=.495; PF-Ind: $r(49)$=-.086, p=.555), or the

quantity of solution ideas (PF-Coll: $r(68) =.32$ $p=.793$; PF-Ind: $r(49)=.173$, $p=.233$). Overall, there was no positive link between students' solutions and their learning outcome.

Table 2. Quantity and quality of solutions from individually and collaboratively learning students

	PF-Coll			PF-Ind		
	M	SD	N (dyads)	M	SD	N
Quality of solutions	4.97	2.1	34	4.18	2.57	49
Quantity of solution ideas	4.53	1.8	34	4.12	1.92	49

In conclusion, when comparing whether collaboratively or individually learning students generated more and qualitatively better solutions, we found a small and statistically non-significant advantage of collaborative over individual learning for both the quantity of solution ideas and quality of the first solution. Still, during the collaborative problem-solving process, students might have iteratively improved their solution by discussing strengths and weaknesses of their solution in ways that our analysis could not yet capture. In order to support this conclusion, our next step is to investigate how collaboratively learning students developed their solutions in the course of the discussion, by analyzing students' verbal process data.

In line with the aforementioned research on PF, we further investigated whether there was a positive link between students' solutions and the learning outcome. We were not able to replicate this link, as other PF-researchers before us (e.g., Loibl & Rummel, 2014). One possible explanation for the missing correlation in our and other previous studies might be the short learning time and in our case a domain specific issue that is the persistence of students' misconceptions about fractions which were reflected in their solutions. In other words: Students' misconceptions were too persistent to be resolved prior to the test phase. An indication in this direction is that students' average scores on the post-test still fell short of the maximum score (PF-Coll: $M= 10.31$, $SD = 2,45$; PF-Ind: $M = 10.8$, $SD= 2.41$ out of 17 points). In a next step of analysis we thus aim to investigate how students' misconceptions which will be extracted from the verbal process data are linked to students' posttest scores.

Another possible explanation may be that although students were asked about the same knowledge components (KC; Koedinger, Corbett & Perfetti, 2012) as for example comparing two fractions with unlike denominators and numerators during the problem-solving and the test phase, the differences of superficial characteristic between the PF problem (i.e., concrete situation) and some test items (i.e., abstract situation) was too large. Therefore, students may not have been able to recognize the KCs in the learning and test phases as identical. For future research, we thus propose to either keep also superficial characteristics of the to-be-solved problem and test items as identical as possible or to ask students' to generate the KCs by themselves while solving test items. In sum, the question of how students' solutions are linked to students' learning outcome cannot yet be answered.

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Student Conceptions of Expertise

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Abstract: We report on student beliefs about what constitutes expertise. Our population is a group of first-generation and deaf/hard-of-hearing students participating in a pre-matriculation university program designed to encourage reflection and metacognitive practice. Students first worked in small groups to articulate criteria that defined expertise and then engaged in a class discussion in which a formal definition was developed. All activities were recorded and student discourse analyzed, revealing a nuanced and evolving understanding of expertise.

Keywords: epistemology, expertise, student understanding

Introduction

Incoming student expectations about course content and epistemology (e.g. Redish et al, 1998) have a significant impact on student learning. Less well studied, however, is the student conception of expertise, the traits that define mastery of a subject. Explicit discussions of expertise and success -- especially among at risk or underrepresented groups -- can develop students' self-assessment skills and thereby improve their persistence in college (Mani 2012). The differences between experts and novices have been studied in a variety of contexts (e.g. Macnamara, 2014), however, novices' perception of expertise is understudied. Motivated by work that suggests metacognitive framing (Elby, 1999) can influence learning, we study first generation (FG) and deaf and hard-of-hearing (DHH) students' perceptions of expertise in a pre-matriculation university program.

Theoretical framework

We focus on two different areas of research on expertise: the differences between experts and novices and the types of practice that may allow one to transition from novice to expert. Chi (2006) summarized the different ways that experts display mastery, including quickly generating best solutions (e.g. in chess, de Groot 1965) and detecting features in a problem or situation that remain hidden to novices (Chi et al., 1981). Experts spend time analyzing problems qualitatively, monitoring their status of comprehension, an important metacognitive trait. This is particularly noticeable in physics (e.g. Larkin et al., 1980), where students tend to work backwards from what is asked while experts work forward, starting with the information given. Macnamara et al. (2014) investigated the effects of deliberate practice on improving expertise. Through meta-analysis of 88 studies, they found that deliberate practice could only account for some of the variance in performance, with the amount explained varying widely across disciplines and no more than 26% in any discipline. An important absence in all of this, however, is the novice's *conception* of what is meant by expertise. That is, what differences does a novice perceive exist between their current state and that of an expert. Work on self-assessment (e.g. Dunning & Kruger, 1999) suggest that novices do not understand the significant gap that exists between them and an expert and, in particular, do not even recognize important specific areas in which they need to improve. This is complicated by the tendency to interpret experiences/feedback in a way that supports a pre-conceived narrative of one's expertise. (Crictcher & Dunning, 2009) Put simply, novices will inflate the importance of characteristics they believe they possess in order to justify their self-assessment as experts. In this study we directly ask novices to discuss traits that *they believe* constitute expertise.

Context and methods

This study analyzes discourse from twenty incoming undergraduate majors in STEM disciplines at a large, Northeastern comprehensive institution that participated in a two-week summer experience designed to foster metacognitive practice. Of the twenty students studied, all were drawn from at-risk populations: fourteen were FG and six were DHH, of whom three communicated primarily through American Sign Language. (Multiple interpreters were present to facilitate communication, and DHH students' statements are taken from the interpreters' communications.) Immediately prior to the large group discussion analyzed, students worked in small groups (3-4) on an activity in which they compared two documents describing climate change and global warming. Documents were distilled from prior student writing as well as professional articles intended for non-scientists.

Students were told that an "expert" wrote one document and a "novice" wrote the other and their task was to determine which was which. Little instruction or guidance was given; in particular students were not given criteria by which to make this determination. After working in their small groups for an hour, the students gathered in a large circle for a more general discussion about expertise. The instructor started the conversation by asking students how they decided which papers were written by experts or novices. The students' conversation later shifted organically into a broader discussion about expertise and what makes someone an expert. All activities were videotaped and transcribed and discussion elements (fragments of conversation consisting of 1-5 sentences) codified according to an emergent rubric adapted from Chi (1981). Sample fragments include the following, coded to indicate communication as a marker of expertise:

> Also the tone of how it is written…I think if you can read it, you can hear it in the voice.

and the following, coded to indicate teaching as a maker:

> One of the main differences [between the papers] was that one was telling you the definition while also teaching, while the other, I don't know if it was right or not 'cause I don't know the definition, it just seemed like 'alright here is the definition.' It seemed that the the other one said, this is the definition and you can see what happened. He puts it in perspective for you.

Video discussion elements were reviewed and entered as source data into NVIVO (NVIVO, 2012). From this, it emerged that the student discourse could be parsed into coherent fragments, 1-5 sentences in length, that articulated a single idea. Ideas were sorted into ten rubric codes, shown in Table 1, that emerged from comparing the video data with categories identified by Chi (1981). Two researchers independently coded half of the discussion elements and established an inter-rater reliability of >85% for each code. A single researcher then coded the remaining elements, and a third researcher reviewed the emergent themes.

Table 1: Coding rubric used to categorize student comments

Rubric Code	Qualities contained in
Communication	Comments about syntax, diction, vocabulary, and confidence shown in communication.
Teaching	Comments that cite the ability to teach as evidence of expert understanding.
Self-Awareness	The ability to self-monitor one's understanding and accurately assess one's expertise.
Relative Scale	Acknowledging that expertise is relative to the understanding of others in the field.
Domain Specific	Statements that acknowledge the domain-specific nature of expertise.
Resourcefulness	Comments that cite the ability to access relevant information with relative ease.
Gradual Scale	Statements that recognize the gradual progression from novice to expert understanding and the amount of time spent working in a domain as evidence of expertise.
Deeper Understanding	Ability to see patterns and qualities within the domain. Includes ability to apply knowledge to new contexts and focus on why something happens, rather than just how.
Interest	Comments about one's dedication and curiosity about the topic.
Counter Argument	Statements that argue against one of the criteria described by the codes above.

Findings

Students argued both for and against individual elements as evidence for expertise. The relative frequency (fraction of coded statements) of elements over the forty minute discussion is shown in Figure 1. Positive values indicate supporting statements; negative values (shaded red) argue against the trait as representative of expertise.

The first part of students' expertise discussion was in response to the instructor's question on how they decided on whether a paper was written by an expert. The primary evidence cited was terminology: using words correctly and straightforwardly was seen as a sign of expertise, as was perceived confidence. Some students reversed these criteria, suggesting that simpler terms indicated an expert who could explain content clearly. Some disagreed with written communication as a criterion for expertise, suggesting that some experts could simply not be skilled at expressing their understanding. Others felt that this skill was a part of expertise, and knowing how to express ideas reflected one's understanding. While there were disagreements in whether written communication was indicative of someone's expertise in the topic of the writing, the discussion prompted students to consider other qualities of experts beyond their initial task of determining expertise through writing.

Throughout the discussion, students often debated about the ability to teach as a marker of expertise. Some students felt that the ability to teach a topic was a necessary marker of expertise. While a novice might be

able to explain or define something, an expert would also offer perspective. One student placed teaching at the highest level of expertise (e.g. teaching a topic leads to true understanding). This same student then immediately questioned this by wondering aloud if "creating" was a higher level. Another student offered a personal experience of teaching a class for a week and yet still not being an expert. Students used the example of knowing how to speak, but not teach, a language, and cited Einstein as an expert, regardless of his teaching ability. Interestingly, as students continued their discussion, they began to separate teaching from expertise.
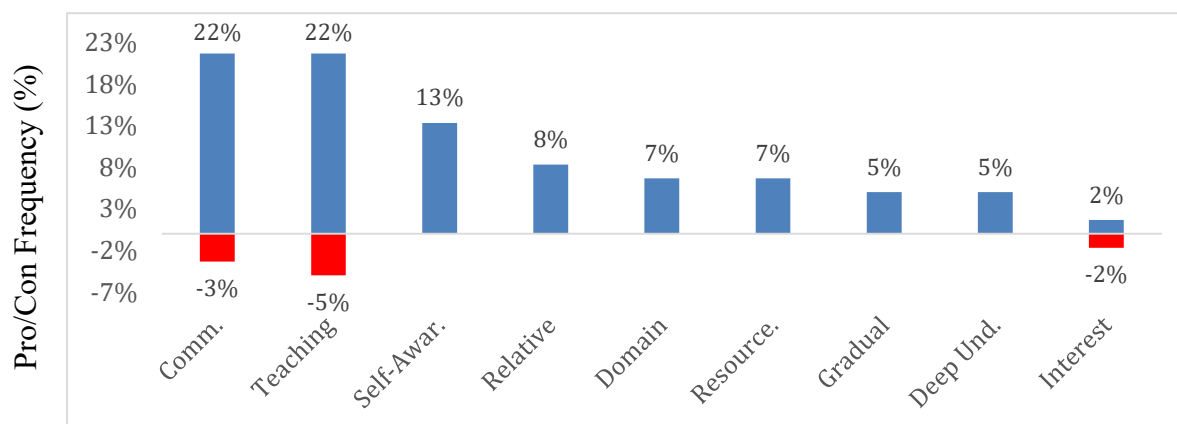
Figure 1. Expert criteria referenced during group discussion as percentage of discussion elements (fragments of conversation consisting of 1-5 sentences) over the course of a forty-minute discussion. Statements supporting the criteria as evidence of expertise are positive; those contesting are coded as negative.

Students brought up multiple criteria that relate to theories of deliberate practice. Key criteria identified in experts was self-awareness and awareness of available resources, and was often expressed in terms of an academic experience. Specifically, students expressed self-awareness in experts as "knowing when to study more", understanding the limitations of your knowledge and abilities, and correctly recognizing what remains to be learned. Students also recognized that an essential part of expertise is a metacognitive awareness of what it means to be an expert (e.g. Dunning& Kruger, 1999), with this awareness enabling a correct determination of what remains to be learned. Students also brought up the importance for experts to be aware of their cognitive resources and the ability to choose which are most relevant to the context at hand. Students recognized that experts need not know (or be able to instantly recall) all content, but rather possess the ability to marshal resources, techniques and strategies as needed. For students, being deliberate as an expert meant knowing themselves and their limitations, and being able to recognize and use available resources.

Expertise was seen as having two scales. The relative scale compared one's expertise with that of others. The other scale was gradual, with expertise gradually learned or accumulated over time. One student compared his expertise at speaking Spanish relative to his different family members, considering himself an expert compared to his mother, yet a novice compared with his grandmother. Another said that, to other students, he is considered an expert at sign language, even though he feels he is not exceptional. Students pushed the scale of expertise to perceptions at different points in history, noting that discoveries in the past might have been easier when less was known. Students also saw expertise as a function of time. Students can become experts with work, and expertise is not binary, growing over time. Some suggested that simply working over time is not enough (reminiscent of early work by Bryan & Harter 1897), arguing that excitement (or motivation) could also play a significant role in acquiring expertise. As a counter argument, though, one student suggested that interest in a topic makes you an aspiring, rather than actual, expert. For some students, reflective practice itself leads to expertise, yet for others such practice only comes about through interest.

Students recognized the importance of considering depth of expertise, and first mentioned this with regards to writing. Students argued that writing which shows a broader perspective and deeper insight into the concept is likely the writing of an expert. Additional depth occurs when considering the applications of a topic and explanations for why something worked. Students used the example of learning to speak a language versus developing fluency, which they saw as language expertise. A deeper understanding is indicative of expertise, but this deeper understanding is also domain-specific. One student talked of "being an expert in naming things in his dorm" to explain how a student could be an expert in a certain domain. Students highlighted the need to focus on a specific field within a broader subject to become an expert in, rather than a general topic or multiple fields. Students' conceptions of expertise were largely connected to a deep understanding within a specific domain.

Discussion and conclusion

We have presented analysis of a student group discussion about expertise. Their conversation centered around five characteristics: communication, teaching ability, self-awareness, relative expertise, and the domain specificity of expertise. We speculate that the first two arise due to the specific context of students and activity. As the discussion was initiated with a question about writing samples, students naturally begin by considering written expression as a marker of expertise. The external origin or motivation could also explain the presence of counter-arguments, as students did not feel strong ownership of this idea as a characteristic of expert knowledge. Similarly, students just beginning the transition from high school to college have a very limited experience with academic content experts. It is plausible that the high school experience conditions students to see their teachers as experts, and it is encouraging that upon reflection they have the ability to question this belief.

Student discussion evolved to issues that can be understood through the lens of deliberate practice. While not explicitly mentioning deliberation or intentionality, student discussions surrounding self-awareness invoked many of the hallmarks of deliberate practice. Their articulation of resources (cognitive or strategic) is insightful, and recognizes the ability of experts to identify the most promising resource from a larger set. This ability has been seen in prior research as characteristic of expertise (e.g. Chi, 1981). Interestingly, students intuitively apply this to the *process* of becoming an expert, recognizing that practice (time-on-task) alone does not bring about expertise. They recognize that an interest in the subject is needed to provide motivation and self-reflection brings about an awareness of resources that both leads to and defines expertise.

Student conceptions of expertise are a rich new area of research with potential implications for instruction. While some believed characteristics --- primarily metacognitive self-awareness --- are consistent with past research on both differentiating experts and novices and the path to expertise, other elements (teaching, communication) appear grounded in the specific experiences students bring with them. It remains to be seen as to whether students profit from insights into expertise and which, if any, interventions are most effective at helping students grow their expertise. Explicit metacognitive/reflective interventions (e.g. Dounas-Frazer & Reinholz, 2015) have been promising, but additional research is needed on the specific conception of expertise and the consequences that an improved understanding of expertise has on student learning.

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Acknowledgments

Distributions, Trends, and Contradictions: A Case Study in Sensemaking With Interactive Data Visualizations

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Abstract: Data visualizations are transforming how information is communicated. Educators should understand and support how youth reason about these complex representational artifacts. We analyze an interview in which young learners interpreted an interactive visualization as describing both relative distribution and absolute trends, and resolved conflicts related to this dual interpretation by re-aligning mathematical and personal knowledge. This case reflects a need for attention to multidimensional data and narrative design in research on data visualization literacy.

Keywords: data visualization, case study, technology, data analysis

Introduction and background

Novel, narratively driven visualizations of data are transforming how knowledge is communicated in popular media and many professional disciplines. Such visualizations are designed to foreground certain "stories" through data, or to allow viewers to pursue certain lines of inquiry through those data (Segel & Heer, 2010). Sometimes the intentions or emphases of a given visualization, however, might not connect to learners' interests or prior knowledge. Understanding and supporting how learners work with such visualizations—how they find, explore, and critically interpret patterns in terms of the systems they describe—is important as educators seek to integrate data visualization into the K-12 curriculum, and to prepare data literate learners.

Making sense of data requires learners to construct and coordinate understandings of evident or implicit patterns in data, and of the situation for which the data were collected. There is evidence that students can productively engage in this back-and-forth, with varying levels of success. Lehrer and Schauble (2004) showed that, while making sense of a representation, students leveraged contextual knowledge to explain patterns they noticed, often supplementing their own observations of the actual phenomenon. Ben-Zvi and Aridor-Berger (2016) described a pair of students gradually developing connections between their understanding of context and data during a statistics exercise. Schwartz and Martin (2004) argued that when students coordinate between data, representations, and mathematics, they "…go through a process of invention, noticing, and revision that helps them develop insight into the relation between representations and the quantities they represent" (p. 138).

We posit that narrative visualizations—designed to emphasize certain stories or lines of inquiry through complex, multidimensional datasets—can introduce additional complexities to this coordination process. Here, we present a case study that illustrates this complexity. While working to make sense of a visualization illustrating fuel consumption trends, a pair of middle-grade students developed a double interpretation of the data, one focusing on distribution (emphasized in the visualization), and one focusing on trends over time (driven by their knowledge of global energy trends). These two interpretations created logical conflicts that emerged in the girls' interactions with one another and with the visualizations. They overcame these conflicts by re-aligning their interpretations of both the data and the situation. Since many visualizations feature both distributions and change over time, and since we found evidence of such conflations in other interviews, we argue that this paper sheds light on a number of specific themes worthy of further study.

Methods

The DataSketch project studies how middle school youth think and learn about data visualization via interviews, classroom studies, and design activities. Here, we focus on one approximately 45 minute interview with a pair of girls, Aphrodite (6th grade) and Stryker (8th grade; participants' chosen pseudonyms). Both were members of an all-girls after school science club where interviews were conducted, and knew each other prior to the study.

During the interview, participants were asked to look at two interactive data visualizations. For the purposes of this paper, we focus on Aphrodite and Stryker's work with one visualization, described in detail below. The interview was semi-structured, based on an eight-question protocol designed to probe how learners understood and navigated connections between data presented, the intended message of the designers, and learners' understandings of the situation represented. Questions included "What is the message you think this is trying to send?", or "What would you expect this [visualization] to look like in the future?". We used video and screen capture to record participants' interactions with one another, the interviewer, and the visualization.

The visualization

The visualization we used concerns the total primary energy consumption of different fuels in the UK each decade from 1970 to 2010 (Figure 1; EvoEnergy, 2011). It is an interactive tree with circle "leaves" of different colors and sizes. To the right of the tree is a legend with fuel types and corresponding colors; to the left, there is a list of years. When the user hovers over a fuel type, a corresponding percent value is shown on the tree. When a user hovers over the years, circles on the tree change colors to reflect the relative distribution of fuel types for that year. The size of the tree, and position of "leaves", stay the same. Fuel consumption is always presented as a relative percent of energy consumption; and no information about total consumption is provided.
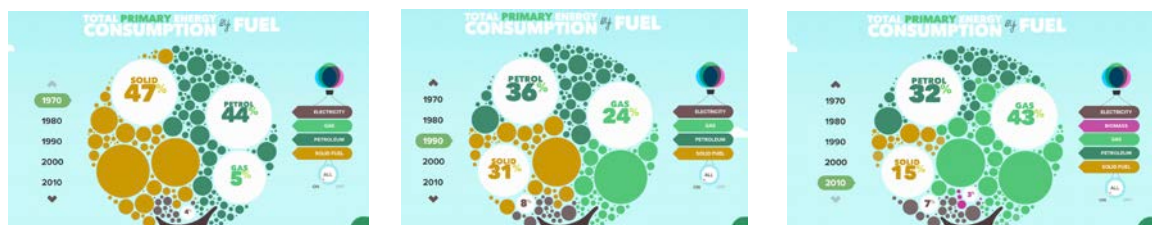
Figure 1. Snapshots of the visualization displaying data for 1970 (left), 1990 (middle) and 2010 (right).

We selected this visualization because some features are relatively conventional (area as percentage), while others are unexpected (apparent meaninglessness of circle size). There are also multiple ways to "follow" data: Using years on the left to view distributions over time, or fuels on the right to focus on only one fuel.

Case selection and analysis

We selected this case as the focus of this short report for three reasons. First, it serves as a particularly explicit example of a phenomenon we have observed in other interviews, whereby learners conflate descriptions of distributions with descriptions of trends over time. Second, the participants were talkative and comfortable working with the data, which makes more explicit and available for study the nature of such conflation. Third, novel interactive visualizations of the sort popular in media and science communication *often* involve data about distributions and trends over time, and as such are likely to trigger similar questions and conflicts. Our analysis identified themes in learners' treatment of data, interpretations, and ways of resolving conflict (Aronson, 1995).

Findings

We report two main findings. First, we will show the girls interpreted data in the visualization in two different ways, as describing (i) distribution and (ii) trends over time. This was evidenced in the girls' references to percentages as describing *relative consumption of fuel*, or change in percentages over time as describing change in *actual consumption of fuel*. We call these usages 'relative measure' and 'absolute quantity', respectively.

These two interpretations can be in conflict. Imagine 5 red marbles are added to a collection of 10 red and 10 blue marbles. The percent distribution of this collection would change from 50% red and 50% blue to 60% red and 40% blue. An 'absolute quantity' interpretation would emphasize the decrease in percentage of blue marbles from 50% to 40%, perhaps suggesting there are fewer blue marbles in the collection. A 'relative measure' interpretation would emphasize that the blue marbles account for a smaller part of the collection.

Next, we will argue that the ways in which participants shifted between interpreting the data as relative measure or actual consumption, and the ways they addressed conflicts that emerged from these different usages, were driven by their negotiations between contextual and mathematical knowledge.

Multiple interpretations of the same data

When introduced to the visualization, Aphrodite and Stryker quickly began attending to and noting changes in the percentages of different types of fuels over the years available in the visualization. When offered paper and markers, they re-arranged the data, grouping by fuel type rather than year and calculating change (Figure 2).
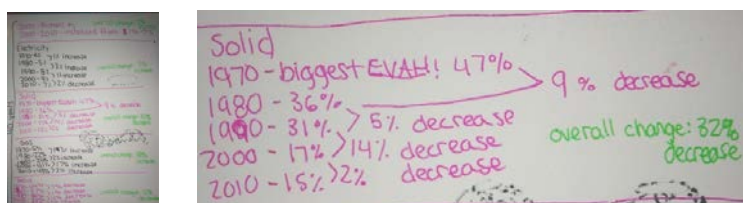
Figure 2. The girls' written work grouped percentages by fuel (left), and computed change over time (right).

Throughout the rest of the interview, the girls treated percentages sometimes as describing relative measures and other times as describing absolute quantities. For example, when she noticed the percent electricity consumption featured in the visualization decreased from 2000 to 2010, Aphrodite was initially surprised and exclaimed "It goes down! Ha!" This implies she was expecting the data to reflect a known trend—a rise in total consumption from 2000 to 2010. Stryker, however, pointed out that since a new fuel type, biomass, was introduced in the simulation "Everything should go down," which implies that she was attending to the distribution of fuels and how the total (100%) is distributed among its parts. These interpretations became more explicit later, when Stryker suggested that in 2020 the visualization would feature "green energy" as a new fuel source:

Stryker: We're adding in another variable. Which [inaudible] everyone will go down some, to make room for green energy.

Aphrodite: True.

Stryker: But I think biomass will still go up.

Here Stryker again attended to percent as a relative measure; suggesting everything should 'make room' for the new variable. But soon after this, while still discussing how the tree might look in 2020, Aphrodite extrapolated a pattern without attending to that distribution, suggesting a usage of percent as an absolute quantity:

Aphrodite: Solid… How much [inaudible]? That's been going down down down down [looking on the screen, browsing along the years].

Stryker: I think we could put solid at 14.

Aphrodite: 14? I feel like it should be a little lower than that.

Stryker: But... [inaudible]

Aphrodite: 13, 12. Cause it's been going down a lot.

While the excerpts above suggest that the two different participants leveraged two different treatments, there was evidence throughout the interview that both participants moved back and forth between both interpretations of the same data. This is illustrated clearly in the next excerpt:

Interviewer: This one [refers to biomass] was the… the most stable one?

Stryker: Yeah.

Aphrodite: 2%... 2% increase.

Stryker: Even.. No one really use it, but, it stayed steady.

Stryker's last utterance combined elements of both relative measure and absolute quantity. On the one hand, she claimed that 'no one really' uses biomass, thus attending to its low percentage in the energy distribution. On the other, she claimed that a 2% increase from 2000 to 2010 meant that biomass 'stayed steady', thus treating these numbers as representing quantities and 2% implying an insignificant change in its absolute consumption.

Re-aligning content knowledge to interpretation of data

These two interpretations of data introduced tensions: between what the girls argued the data showed, their own expectations, and the visualizations' emphases. This tension was reflected in the girls' early reorganization of the data in the visualization, and persisted throughout. The girls stated often that they were concerned about the environment. They described decreases in percentages as 'good' and increases as 'bad', suggested the tree should be heart shaped to encourage users to "love the Earth", and described the visualization's underlying message as "The Earth is gonna die soon." These concerns were not supported by the data, given the girls' dual interpretation. When asked what they notice in general about the visualization, Stryker and Aphrodite noted:

Stryker: So, these... Most of them sadly... [finding total change on the paper] Em... Two of the biggest ones, petrol and solid decreased over the… how long is it?

Aphrodite: Overall it's gas that's been up the most. [inaudible] And… down the most… solid. So gas went up the most and solid went down the most.

Given the participants' environmental concerns, it seems Stryker was preparing to say "most [fuel consumption] sadly *increased*", the use of the word 'sadly' highlighting the environmental consequences of fuel consumption on Earth. When this increase (presumed about absolute quantities) wasn't reflected in the data (intended as relative measure), Stryker paused and changed what she observed about the data, which Aphrodite re-voiced.

This realignment also happened when the interviewer explicitly highlighted a mathematical conflict that emerged from the girls' dual interpretation of the percentages as relative measures or absolute quantities. At some point Aphrodite argued that the (absolute) consumption of petrol did not change "compared to the others", even while both girls argued that car use had increased through the years. The interviewer followed up:

> Interviewer: So, if they use their cars... if we have more cars, actually, than in 1970s, and we use petrol mostly in cars, why do you think it didn't change much? The consumption?
>
> Stryker: There are new ways to power cars now.

Stryker invoked her personal content knowledge—alternative sources of fuel for cars—to justify an inconsistency in their interpretation of the data available, that petrol stayed stable despite increases in car use. Both of these examples illustrate adjustments that the girls made to their descriptions of data, and to their descriptions of the context in which those data were collected, to better align the two throughout the interview.

Discussion and conclusion

Narrative visualizations, designed to be visually pleasing and to emphasize stories with data, are an important part of how information is communicated. These visualizations introduce complexities to the interpretation process of learners: they involve complex, multivariate data, explicitly organized to emphasize a certain point of view or path for investigation. Thus in addition to coordinating understandings of data and context as has been explored in the literature, dealing with narrative visualizations requires learners to coordinate *multiple* possible patterns embedded within the data, and with designers' often explicit intentions.

In this paper, we explored how one pair of middle school learners, Stryker and Aphrodite, navigated this territory. By closely examining the students' discussion, interactions with the visualization and the way they decided to reorganize the data, we found that both participants interpreted the data provided in an interactive visualization of energy consumption by different fuel types in two potentially contradictory ways: as 'relative measures' describing distribution in terms of percentages, and as 'absolute quantities' describing total increases or decreases in energy consumption over time. These dual interpretations created conflicts between the participants' understanding, the data, the representation, and their knowledge of actual energy consumption trends. They addressed these conflicts by realigning interpretations fluidly—reorganizing and manipulating data presented, adjusting interpretations of those data, and adjusting justifications for patterns observed. In addition to the issues of distribution, trend, and conflict emphasized in our analysis, we note that certain interpretations might have been triggered by the way the visualization was designed. For example, the size of the tree stayed the same, which could have led the girls to assume that the total energy consumption had remained unchanged.

This case represents a first step in work on how learners reason with complex, narratively organized data. It details specific themes—the conflation of distribution and trend, and the adjustment of data and interpretation—as possible starting points in this investigation, and highlights ways these issues may manifest.

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Acknowledgments

A User Interface for the Exploration of Manually and Automatically Coded Scientific Reasoning and Argumentation

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Abstract: Scientific reasoning and argumentation (SRA) is a complex process. Thus, analyzing the quality of learners' SRA and presenting SRA outcomes are important research problems. This study attempts to account for these problems by developing a user interface that facilitates learning scientists to analyze SRA, enabling them to evaluate the performance of an automated coding algorithm and supporting them to recognize patterns in the coded data using flexible visualizations. The usability and the comprehensibility of the user interface have been tested by means of a user study in an online performance test. The results indicate that the user interface effectively supports the investigation of SRA.

Keywords: scientific reasoning, user interface, automated coding, visualization, epistemic activities

Introduction

Scientific reasoning and argumentation (SRA) is a complex process, both for learners to engage in and for teachers or researchers to evaluate SRA. For example, in psychological research, the hand-coding of verbal data and the interpretation of manually and automatically coded outcomes can be very demanding. Recent developments have given rise to computer-supported scientific reasoning assessments (e.g., Gobert et al., 2013). Automated text classification techniques developed by computer scientists in collaboration with domain experts may facilitate the process of discourse analysis (Rosé et al., 2008). However, it has yet to be fully understood how technology should present the outcomes of the automated analyses to domain experts. Suitable user interfaces (UIs) shall support reflection on the reliability of automated coding outcomes and to discover previously unnoticed patterns and relations within the discourse data (Suthers, 2001). The aim of this study is thus to develop a UI to aid scientists with no computer science background by fostering their understanding of and work with both machine and hand-coded process data.

The empirical work applied in this study builds on a novel framework of SRA (Fischer et al., 2014), describing it as a process of inquiry. This model identifies eight epistemic activities relevant to SRA: problem identification (PI), questioning (Q), hypothesis generation (HG), constructing and redesign of artefacts (CA), evidence generation (EG), evidence evaluation (EE), drawing conclusions (DC) and communicating and scrutinizing (CS). Previous studies developed a coding scheme to capture epistemic activities of SRA in two professional domains. Their findings in the domain of teacher education (Csanadi, Kollar, & Fischer, 2015) and social work (Ghanem, Pankofer, Kollar, Fischer, & Lawson, 2015) support the notion that the SRA framework may be fruitfully applied in practical domains. In both studies, the researchers realized the need for a tool that offers visual support for coding interpretation. Thus, a UI that provides support in visualizing patterns within manually and automatically coded data has been developed in the present study. An online demonstration of this UI is available at http://reason.ukp.informatik.tu-darmstadt.de:9000.

Key requirements for visualizing epistemic activities

To create a suitable UI, which helps learners and domain experts to visually analyze manually and automatically coded data, we formulated the following requirements in accordance with its target users:

R1. The UI must be accessible and usable without any complex installation.

R2. Terminology should be aimed at its target users, unfamiliar terms and visualizations must be explained.

R3. To support the analysis of SRA, it must be possible to visualize both manually and automatically coded data of a sequential nature.

R4. Users must be able to look at the information used by the automatic classification algorithm to understand its relation to the codes better.

R5. Users must be informed about the performance of the automatic classification for given codes.

Previously developed tools, that support researchers' understanding of results from automatically coded data (e.g., MINERVA; Stoffel, Flekova, Oelke, Gurevych, & Keim, 2015), exhibit limitations of usability due to their exclusive focus on users with expert knowledge in automatic coding. Other systems for visualizing text classification components (Heimerl, Jochim, Koch, & Ertl, 2012; Lamprecht, Hautli, Rohrdantz, & Bogel, 2013) and automated coding tools that enable text classification for large amounts of data (e.g., LightSide, Mayfield & Rosé, 2013) are not suited for sequential data. The present UI is different from the above tools because it fills a specific gap and targets learning sciences students and domain experts with little or no background in computer science.

Developing the UI

Step 1: Manual and automatic coding of SRA

The development of this UI relied on two datasets from earlier studies (Csanadi et al., 2015; Ghanem et al., 2015). These studies developed a segmentation and coding scheme on epistemic activities of SRA (Fischer et al., 2014) for professional problem solving. Think aloud protocols and discourse data were segmented and coded for further analysis. Their segmentation into propositional units reached reliable proportions of agreement between 80% and 85%. The coding scheme proved to be reliable at $\kappa = 0.69$ and $\kappa = 0.68$. Results for the automatic coding of SRA were gathered from Spari (2015). Here, DKPro TC (Daxenberger, Ferschke, Gurevych, & Zesch, 2014) was used to perform machine learning based on features (see Requirement 4). A wide range of features were extracted, e.g., average word length and number of pronouns for each segment. Codes were then automatically assigned based on the features and the sequence of segments.

Step 2: Design of the user interface

While existing tools focus on the selection of appropriate features such as n-grams and syntactical information for a given coding task, the present UI aims to support learners and domain experts in understanding a) how SRA (and related sequential datasets) is manually coded, and b) how an automatic algorithm codes the same data. This requires suitable and flexible visualizations for sequential data. The present UI addresses a) in three interfaces: a segment listing, a label distribution histogram, and a progression graph visualization. In the segment listing, all segments of a transcript are shown in chronological order, with both manual and automatically assigned codes. The label distribution intends to give a quick overview of the frequencies of different codes. The progression graph (cf. Fig. 1 left) deals with the sequential nature of SRA by displaying a graph that shows the frequency of each code for a transcript over time. To do so, the occurrences of all codes are computed for different, flexibly configurable time intervals of a text.
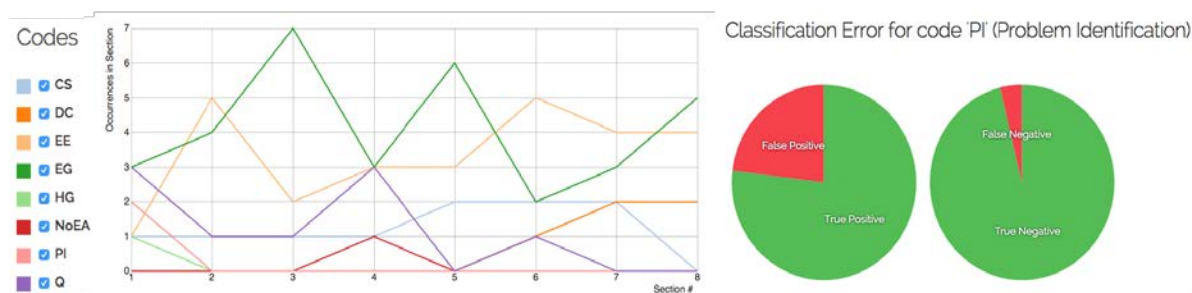
Figure 1. Parts of the UI: The progression graph (left) and classification error visualization (right).

Two further visualizations address b): feature value distribution and the classification of error types (cf. Fig. 1 right). The former shows the values for each of the features that have been used by the automatic coding algorithm to determine the code for a segment. Users can inspect the distribution of values for a given feature and code. The error classification visualization provides an insight into the reliability of the automatic coding by allowing for a comparison of the accuracy between them, as well as by listing absolute and percentage number of samples for each error type (e.g., false positives). In order to make visualizations accessible to users with little or no knowledge of automatic coding, simple representations have been preferred over more complex ones (Guyon & Elisseeff, 2003).

Method and design of the user performance test

An online performance test was developed to test the usability and comprehensibility of the UI. The sample ($N =$ 20) for this test included members of an interdisciplinary research group dealing with SRA ($n = 13$), students of a Learning Sciences M.A. Program ($n = 4$), and postgraduates of a computer science laboratory ($n = 3$). All participants were students or employees at German universities.

The UI was demonstrated using two transcripts of think aloud protocols of pre-service teachers solving an authentic problem from a study conducted by Csanadi et al. (2015). The results of both automatic and manual coding were displayed in the UI. The test consisted of five sections, as follows:

Distribution of codes: We asked for the most frequent code in a given protocol, both for the automatic and the manual coding.

Domain-specific questions: We asked participants to decide whether a protocol indicates hypothetico-deductive or inductive reasoning.

Features: Participants had to compare the predictive power of three features for several codes.

Appraisal of automatically coded results: Using the classification error visualization, participants had to evaluate the accuracy of automatic coding. We asked for the highest number of 'True Positive' and 'False Positive' classifications, as well as for the highest accuracy.

Usability judgement: We asked participants to rate the usability of the UI in general and in particular, its usefulness for present/future research.

In addition to these five-point Likert-scale items, we asked participants to provide an overall feedback.

Findings

Table 1 shows the number of participants who answered correctly, incorrectly, or indicated an inability to answer, to each question type. For the domain-specific questions, participants were additionally asked to specify the visualization they used to find the answer. While the task was specifically designed towards the progression graph visualization and ten domain experts used it to solve the task, it could also be solved using the simple listing of segments with their codes, as the remaining three domain experts and two additional participants did. Only two participants incorrectly tried to solve these tasks using the distribution of codes, which was not possible as the task relied on the sequence of codes. On average, the participants rated the usefulness of the UI (1 = Not useful; 5 = Very useful) at 3.45 (domain experts: 3.23). The applicability of the UI to their present and future research was rated on average at 3.15 (domain experts: 3.08). The UI's ease of use (1 = Very hard/confusing; 5 = Very easy) was rated on average at 3.1 (domain experts: 3.15).

Table 1: Performance Test Outcomes: Number of Participants (Including Domain Experts)

		Participants (Domain experts)		
		Correct	Incorrect	Unclear
Evaluation of Descriptives	Distribution of codes	20 (13)	0 (0)	0 (0)
	Features	16 (11)	2 (0)	2 (2)
Domain-specific questions: Identify reasoning types	Identification of first text (Hypothetico-deductive)	16 (13)	1 (0)	3 (0)
	Identification of second text (Inductive)	10 (8)	2 (1)	8 (4)
Appraisal of automatically coded results	Compare accuracy of two codes	14 (9)	6 (2)	0 (0)
	Find correct statement about the performance of a feature	14 (9)	6 (4)	0 (0)

Conclusions and implications

Overall, this study demonstrates that the UI represents progress towards developing a comprehensive and effective tool for domain experts who are not overly familiar with computer science technology. R1 (easy accessibility) was addressed by implementing the system as an online interface that can be accessed on any modern web browser. R2 (user-friendliness) was met using "familiar" terminology and textual cues. The majority of users reported little to no difficulty understanding the interface or using it to solve the presented tasks, which was also shown by the high rate of correctly answered questions (cf. Table 1; for the easier questions, 100% correct answers were obtained). R3 (visualization of process data) was addressed by the segment listing, label distribution histogram, and progression graph interfaces. Here, the users experienced the most difficulty in a) identifying the reasoning type (this might be the result of a lack of knowledge in the domain of SRA) and b) understanding the performance of the automatic coding (possibly due to unfamiliarity with machine learning). R4 and R5 (feature

value distribution and error classification visualization) were each addressed by their own interfaces. The average ratings from the related questions demonstrate that these visualizations tended to be more helpful than confusing. Inquiries about the generalizability of the UI in the research of the participants were also slightly more positive than negative. The same was recorded regarding the UI's ease of use. This feedback will be taken as encouragement to invest further effort in the development of the UI.

From a practical viewpoint, this tool is already able to support teachers when conducting spontaneous assessments of their students' SRA based on the visualization of the automatically coded texts. The UI might be further extended to provide automated feedback to students (e.g., about the type of reasoning they used), thus enabling both adaptive and adaptable support. Some limitations of the present study include the lack of a control group in the survey (i.e., a group of users who had to solve the same tasks/questions without the current UI or with another tool) or the inclusion of additional (potentially better) machine learning models, which might have increased the users' understanding of features and their meanings.

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Designing Outdoor Learning Spaces With iBeacons: Combining Place-Based Learning With the Internet of Learning Things

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Abstract: This paper presents a collective case study of learners using mobile technology to engage in place-based science learning in an Arboretum. Our work investigates how proximity-based computing mediates youth's engagement in scientific observations and conversations in their Appalachian community. We draw upon theory from informal learning, place-based learning, and context-sensitive educational technologies to inform the research. Data from 26 children in a summer camp program include log files, field notes, and video-records. Our findings illustrate how an iBeacon system supported children's playful and scientific engagement (including in observational practices). We provide insights into designing for learner-centered mobile computing that moves beyond presenting just-in-time information to creating digital-physical spaces where learners engage each other and natural objects to support their interests in science.

Keywords: informal learning, mobile computing, pedagogical design, science education, gardens

Introduction

As mobile technologies become ubiquitous tools in educational settings, new opportunities have been created for everyday objects to become connected to mobile devices. These connected devices have resulted in digitally-augmented learning environments, which are referred to as the Internet of Things (IoT) (Trappeniers, Feki, Kawsar, & Boussard, 2013) or Internet of Learning Things (IoLT) (Selinger, Sepulveda, & Buchan, 2013). In the IoLT, designers connect computers to objects to bring together digital resources and physical places. Our research and development agenda seeks to inform science learning experiences with design principles for technology-enhanced pedagogies. Specifically, we are investigating how informal learning institutions (ILIs), such as zoos, gardens, and science centers, can adopt iBeacon technologies to augment exhibits to engage visitors in interactive learning activities within and about their community. As such, our work conceptualizes how proximity-based technologies, informed by an IoLT perspective, can support youth to learn about biology, geology, hydrology, and ecology in the places that matter to their daily lives.

Theoretical framework

Conceptually, our research and design efforts use an IoLT paradigm to make visible the scientific phenomena present (Eberbach & Crowley, 2009) in an ILI in ways that align with instrumental and social disciplinary practices. Through this work, we transform object-oriented institutions into child-centered learning spaces as we draw upon three literatures: *informal learning, context-sensitive technologies*, and *place-based learning.*

The *informal learning* perspective (Bell, Lewenstein, Shouse, & Feder, 2009) acknowledges that people's sociocultural experiences, prior knowledge, and purposes/agendas for engaging in activities need to be honored in the design of learning experiences. Informal learning processes that we support with our design work include (a) meaning-making through talk where learners understand new phenomena through social interactions (Leinhardt, Crowley, & Knutson, 2002) and (b) making, drawing, or developing artifacts in order to elaborate, share information, and connect and build ideas (Kafai & Resnick, 1996).

The learning with mobile technology literature considers the learner's interactions with their physical location, others, and the technology as part of *context-sensitivity*. Context-sensitivity is often associated with types of augmented reality (AR) (Dunleavy, & Dede, 2014). Sharples (2013) asserted that context in a learning environment is more than just the setting, instead context is negotiated moment-by-moment through learners' interactions with the physical location, technology, material resources, and other people. We also drew heavily on research on science learning with mobile computers (Chen, Kao, & Sheu, 2005; Huang, Lin, & Cheng, 2010; Kamarainen, et al., 2013; Land & Zimmerman, 2015; Looi, et al., 2010; Rogers, et al., 2005).

Place-based learning (Smith, 2002) aims to ground learning experiences in community perspectives to illustrate how global and abstract concepts manifest in local places and spaces. Place-based activities recognize learners' everyday experiences as assets to future learning. When place-based learning is combined with context-

sensitive technologies, mobile computers become tools for learners that mediate connections between a local setting and the broader disciplinary perspectives (Zimmerman & Land, 2014).

Technological setting: The *Places* iBeacon system

The iBeacons development platform (*Places)* includes a content management system (CMS), the *Places* app deployed on iPad™ tablet computers, a server that hosts the CMS and data analytics, and iBeacons placed at biological, geological, ecological, and hydrological exhibits within the Arboretum. We used Gimbal™ iBeacons that were battery-operated Bluetooth Low Energy (BLE) transmitters. iBeacons transmit signals to a user's mobile device in ways that allow the device to detect a learner's proximity to the iBeacon. With the fine-grained proximity information, the *Places* app pushes relevant content and learning activities to children and families.

The research team developed a CMS to communicate to the *Places* app via the Internet. In the CMS, the researchers loaded customized maps of the Arboretum exhibits, diagrams, photographs, and text (written at a 3rd-grade reading level for children ages 8-9) as well as unique codes found on each iBeacon. The CMS was designed so that a learning designer could connect unique educational resources to each iBeacon in its database. When in the Arboretum, the *Places* app launches the appropriate exhibit map when it detected an iBeacon that was identified on that map. The iBeacons allow the *Places* app to push information to learners at the proximity level of a specific tree specimen or exhibit component (at a precision that other location-aware technologies such as GPS nor QR codes cannot easily accomplish). This specificity of proximity enables the IoLT perspective in ILIs, because iBeacons can support a visitor to compare and contrast relevant features of two trees or two sculptures that are just meters apart.

Figure 1. When iBeacons are detected, the *Places* app launches a map for children, which highlights the trees with additional learning activities.

For the two case studies presented here, learners were given iPads to use with *Places* in the Arboretum. (Note: After the *Places* app is downloaded, the Internet is not needed). As the children reached a proximity threshold specified by an algorithm set by researchers in the CMS, the iBeacon triggered the display of content on the iPad that included a learning activity and scientific information. During the learners' visit to an ILI, the *Places* app used the iPad's hard drive to store data about the learners' interactions with and proximity to each iBeacon. The data captured by the *Places* app contained an iPad-specific ID, iBeacon ID, content ID attached to the iBeacon, first access time, number of total access points, and last access time. When the *Places* app next accessed the Internet, *Places* transmitted non-personally identifiable log file data back to the *Places* server with the users' consent (and assent).

Methods

The overarching methodology is a collective case study to consider the unique features of a case (i.e., each iBeacon-enabled learning experience) as well as to compare and contrast two cases. We selected the Arboretum at Penn State as our study site as it is a prototypical outdoor ILI. The Arboretum has a pollination garden, a model cave, children's garden, live specimens, sculptures, and various scientific representations. Learners in Case A include 26 summer camp youth aged 6-10 learning about caves, and learners in Case B include 24 youth (from the same summer camp) learning about fruit. Learners worked in small groups with the teachers from the camp to use the *Places* app and iBeacon system.

In order to investigate how an iBeacon mobile computer system can be designed to support learners' science learning in ILIs, this study asks the following two questions:

- What types of conversations do learners have while using the materials? What types of engagement patterns can be observed related to playful and/or scientific learning?

Data collected include: (a) observations of small groups of children using the *Places* app and iBeacons at the Arboretum, (b) learning analytics of small groups' actions based on iBeacon proximity; (c) small groups' photographs and drawings, and (d) recording from digital video-cameras and GoPro® point-of-view cameras.

Observations of children at the Arboretum at Penn State

Each researcher followed one small group of children on-site. Researchers did not ask questions of the children but assisted with technical issues as needed. Field notes were compiled into a database, and episodes were identified related to (a) learner experiences with wayfinding and usability of the app and (b) learners' discourse related to their observations of trees, the technologies, and science concepts. The episodes identified on the field

notes were coded from our theoretical framework as well as by emergent codes. Multiple researchers worked together on transcripts during team meetings to confirm themes and patterns related to the research questions.

Learning analytics of children using the *Places* app

From the *Places* app, the research team collected detailed logfiles at the level of each small group, rather than individual learners. These logfiles from small groups were coordinated to the fieldnotes so that we could align the online data with on-site observations. We collected data that included the mobile device ID, content set accessed, iBeacon accessed, timestamp, and learners' digital photographs. Logfiles were exported into Excel for analysis. From these data, we determined the time spent at each plant specimen, the learning pathway taken across the Arboretum, and breadth and depth of the science content that each group accessed.

Video-recordings of the learners at the Arboretum

We collected video-recordings of the children at the Arboretum. Team members made content logs where key actions were identified. Researchers noted connections to prior knowledge, connection to concepts presented, use of representational forms, and talk that described or explained relevant scientific phenomena. The team held interaction analysis sessions where researchers described, documented, and interpreted the learners' activities in the Arboretum. Narrative accounts of each group of learners were developed as were analytical memos related to themes of place-based learning, informal science learning, play, and technical use issues.

Findings

Case A: iBeacons assisted learners to coordinate ILI exhibits' content to their local community, its history, and the learners' playful interests

In Case A, we developed a 60-minute tour that showed learners models of phenomena that were of geological, hydrological, and biological importance to their community. An important theme on the tour was the way that water transformed the landscape and how the land transformed the water. All 26 children were observed to engage in playful and scientific discussion around the iBeacon content. The first excerpt illustrates how four children were able to connect *Places* app science content to a life-sized model of a cave:

- At the iBeacon trigger for the cave, the *Places* text read: "Do you see where the water may have dissolved the rocks?" Cora pointed up to the stalactites. Then, Alex, Zoey, and Sawyer also pointed at the stalactites. Sawyer said, "see the white rock". Alex and Zoey added, "and the white stalagmites".

The excerpt with Cora, Alex, Zoey and Sawyer illustrate how the text triggered by an iBeacon could act as a prompt to support observations of small (less than 10 cm) stalactites that grew on the ceiling of the model cave.

Even while observing in the garden, learners added imaginative role-play elements to the iBeacon content. In this second excerpt, Sebastian added a time machine element to iBeacons activity, pretending that he could go back in time when his local community was covered by ocean to explore the prehistory of his community:

- Sebastian: Oh yeah! This is our next destination. This has to be. Is this real coral? Ohhhh, the trannsssmittter! Look! I'm putting this in here. Locked coordinates with black rock. ((He puts a rock in the hole in the coral model.)) Locked in coordinates. Look this fits in here perfectly! I'm going to the beach . . . ((singing)) yeah!

We interpret Sebastian's time-travel interactions to be consistent with expectation for play (and fun) in an ILI setting. While we designed structure in our iBeacon program for *Places,* we took care not to over-structure the program — we left space for learners' interests (and personal agendas and aims) alongside the scientific aims.

Case B: iBeacons supported observational practices across a large exhibition

In Case B, we created a 60-minute observationally-focused tour that applied one concept — the biodiversity of fruit. We placed iBeacons on trees that had visible evidence of fruit in the Arboretum, but we encouraged the groups of learners to find other plants or trees with fruit. The 24 summer camp children engaged in observations that resulted in playful, descriptive, and conceptual discussion of plants, as shown by these three excerpts:

- Playful talk: After investigating a tree and observing its many pinecones, Sebastian raised his hands above his head to imagine that he was a pinecone similar to those he saw: "I'm a very small pinecone".
- Descriptive talk: A teacher asked if the children observed any differences between two crabapples trees. The children described differences in tree size, tree shape, bloom color, and branching pattern.
- Conceptual talk: While looking at a tree, Sawyer and Violet observed strawberry plants at its base. Violet connected the berry plants to others she had seen: ". . . they usually bloom in the early spring".

These three examples from our dataset learners engaged in scientific observations of the selected iBeacon-ed trees as well as other content that piqued their interests. These three excerpts were typical of others' scientific and playful interactions related to observing plants at the Arboretum.

Cross-case discussion and implications to learning with mobile technologies

Across the two cases, we found that both play and science learning — especially related to observational practices (Eberbach & Crowley, 2009) — were supported when we integrated an iBeacon system into a summer camp program. In keeping with the goal to design an IoLT experience (Selinger, et al., 2013) for youth, the *Places* iBeacon system delivered content, question prompts, and activities to children in the Arboretum in a manner that supported them to look deeply at plants. We also found that social interactions occurred in the form of science-related learning conversations (Leinhardt, et al., 2002) of both a descriptive and conceptual nature. This project adds to the understanding of how to blend context-sensitive technologies with place-based perspectives on learning because the design principles were supported by our case analyses to align to the orienting meta-principle of augmenting outdoor spaces to reveal scientific aspects that might not be visible to novice learners. Based on our analysis, we posit that by empowering young learners to explore ILIs with iBeacon systems (or similar context-sensitive educational technologies), youth can follow their own interests as they engage in the science practice of observation. Learners can also use iBeacon systems to control the depth and breadth of science content presented, based on their proximity to pre-selected specimens and exhibits.

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Acknowledgments

Agentic Trajectories: Development and Learning in a Project-Based High School for Marginalized Students

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Abstract: Traditional approaches to schooling can marginalize already vulnerable students, preventing them from learning; we explore how agency might play a role in supporting such students to develop as learners in a project-based high school that employs design pedagogy. We first examine whether agency can explain variance in standardized mathematics scores. Regression analysis indicates home language and agency had a significant effect on mathematics scores. We then turn to data collected through extended participant observation to characterize decisions students make. Based on these, we detail a developmental agency trajectory: *dis/engagement* agency serves as a covert means for students to learn; *makerly* agency serves as an entry point for students to explore and develop interests, and *designerly* agency allows students to take ownership of design problems and learn as they do so.

Major issues addressed and significance

The value of students having agency—opportunities to make and carry out decisions about how and what they are learning—is contested in research; some view agency leading to increased learning (Pellegrino, 2004), while others critique this stance (Schwartz & Okita). Students from high socio-economic groups are likelier to receive experiential, high-agency approaches to instruction, creating opportunity gaps (Milner, 2012) that reproduce and further widen existing achievement gaps. We investigate whether high agency in a design-based school that serves marginalized students relates to achievement. We characterize the types of decisions students make and consider how such decisions create developmental trajectories for these students. We were guided by research questions: (1) Do demographic variables, attendance, and measures of agency explain variance in standardized mathematics scores? (2) What kinds of agency do students have at a project-based school that serves students marginalized by traditional schooling? How might these create or lead to learning opportunities?

Theoretical approach

We define agency as making decisions, and focus on decision that affect learning. Agency is socially-constructed (Ahearn, 2001); decisions and actions are constrained or afforded by social structures, which in turn are shaped and reshaped by decisions and actions (Bourdieu, 1977). Thus, agency "progressively emerges out of interactions between participants and their activities" (Damşa, Kirschner, Andriessen, Erkens, & Sins, 2010, p. 115). Agency depends on the *opportunity* structure (Narayan & Petesch, 2007), which can be thought of by considering whether there are opportunities to make decisions, whether students actually make decisions, and whether they are satisfied with the outcomes (Alsop, Bertelsen, & Holland, 2006). In a project-based learning setting, the locus of control is shifted more to the students than it is in traditional settings (Brown & Campione, 1994). In project-based settings that employ design pedagogy, even more control may be granted to the learners; designers occupy an *agentive* position. Design pedagogy positions students as designers working on authentic problems for actual clients and customers (Edwards-Vandenhoek & Sandbach, 2014).

Methodological approach

The participants were students enrolled in an urban, not-for-profit charter school in the American Southwest. The school aims to have high impact by serving students who have been marginalized by traditional schooling. The original sample included 522 students (every student enrolled during a one-year period). The school population is *highly* mobile. We selected students who had complete data for all measures, which resulted in a sample of 44 students (~one third of the students enrolled/attending regularly during data collection). The participants were predominantly male (n=30). Thirty-eight identified as Latino/a, four as White, and two as American Indian. Thirty-two students reported speaking English and twelve reported speaking Spanish at home. The mean attendance rate for Trimester 2 was 93% (*SD*=9.16%).

A survey with 5-point Likert items adapted from Alsop et al. (2006) was given at the beginning of the trimester (n=105). Discovery Education (DE) assessments (n=114) were given in the middle of the trimester. Qualitative data were collected through participant observation, resulting in ~1000 pages of field notes, and ~400 hours of audio/video records, organized into a searchable database.

We modeled variance in DE math scores as a linear combination of attendance, home language, and two agency variables: (1) I have had opportunities to make decisions related to this project. (*M=3.43, SD=1.02*); (2) When I made a decision related to this project, I was happy with the result. (*M=3.77, SD=.77*). We conducted interaction analysis (Jordan & Henderson, 1995), beginning with a general analytic focus—agency, identifying particular moments of agency situated in and reflective of the school practices. We grouped these into three types and share representative vignettes for each.

Findings

Regression modeling

We modeled DE mathematics scores (*M=1573, SD=74*). In model 1 (Table 1), a multiple linear regression was calculated to predict DE mathematics scores based on attendance and home language and was significant, ($F(2, 41)= 4.42, p<.05$). Speaking English in the home predicted higher DE mathematics scores, but attendance was not significant. In model 2, we added reported agency, and this was significant, ($F(3, 40)= 5.12, p<.05$). Students who reported higher levels of agency tended to have higher DE mathematics scores. In model 3, a multiple linear regression was calculated to predict DE mathematics scores based on attendance, home language and satisfaction with the decisions they had made; this was significant ($F(3, 40)= 3.46, p<.05$), but reported satisfaction with decisions was not.

Table 1. Regression models of variance in Discovery Education mathematics scores

	Unstandardized Coefficients		Standardized Coefficients	
	B	Std. Error	β	t
Model 1: attendance and home language				
Intercept	1569.46	108.56		14.46***
Home language	68.02	23.23	.42	2.93**
Attendance	-.49	1.14	-.06	-.43
Model 2: attendance, home language and reported agency				
Intercept	1486.54	108.90		13.65***
Home language	72.81	22.13	.44	3.29**
Attendance	-.49	1.08	-.06	-.45
Reported agency	22.96	9.77	.32	2.35*
Model 3: attendance, home language and satisfaction with decisions made				
Intercept	1533.90	119.66		12.82***
Home language	67.70	23.36	.41	2.90**
Attendance	-.51	1.15	-.06	-.44
Satisfaction with decisions made	9.88	13.60	.10	.73

*p<.05; **p<.01; ***p>.001; Model 1, $r^2 = .14$*; Model 2, $r^2 = .23$*; Model 3, $r^2 = .14$*

Qualitative findings

We present vignettes to highlight three types—*dis/engagement*, *makerly* and *designerly*—of agency we observed, specifically related to learning.

We define *dis/engagement agency* as the choices students make about how to engage with *delivered content*. Some students exhibited relatively traditional indicators of being engaged. Benjamin, for instance, interjected questions as they occurred to him when a guest speaker presented. However, detecting whether a student has decided to engage with particular content can be difficult. For instance, we consider observations of Ivan, a member of a clique of young men who appeared to systematically disengage. On some occasions, they appeared quietly disengaged, staring at their smartphones. While we observed them using their smartphones to socialize, we also observed that staring at one's smartphone can *sometimes* be a means to listen. It can signal to one's peers, "leave me alone, I am busy" and creates a stance of disengagement that is comfortable for many of these students to wear.

2015/01/30 field notes: 11:01am: A video of interviews with people who are homeless is playing. Some students take notes, some don't have notebooks out. Ivan stares at his phone. A student on the other side of the partition continues to play music on his phone, which is audible and increases in volume, making it somewhat hard to hear the video. At 11:08 Ivan asks Mr. F to "get the music turned off."

We see this as evidence of Ivan's dis/engagement agency. We infer that he made this request because he wanted to be able to hear the video that was playing, and not that he simply disliked the music, as the music had been playing prior to the video. Near the end of the project, (2015/03/10) the teachers discussed poverty and homelessness. Ivan was staring at his phone during the beginning of this exchange. Mr. F asked:

Mr. F:	What is poverty? How 'bout that. Who knows what poverty is. Look it up on your phone.
Benjamin:	Ask the Google
Mr. F:	Ask the Google. Ivan's on it. Tell me what poverty is. Look it up.
Ivan:	Poverty is—poverty is where you can be living in a house, but you are on such low income, if not—if any income—you're almost a bum in a house.

We see this exchange as suggesting that Ivan had been attending to the conversation, and further, that Mr. F was aware of this. We do not argue that staring at one's phone should be viewed as evidence that a student is listening, or that Ivan's attention was fully on listening; rather, we argue that when students have developed identities as *failures* and *troublemakers* in response to traditional schooling, they may seek covert ways to engage, particularly when the material is meaningful to them. As another student, Raoul explained to us, "People think we aren't listening, Miss, but we are." Mr. F confirmed that he believed students choose to listen covertly, and that he takes advantage of this as a way to draw students into more active participation.

We define *makerly agency* as students making decisions about the process and form of the things they are making. Viewed from a constructionist lens, the things students make should be meaningful and publically sharable. While the things they make are shared at exhibitions, the making can be rather mechanical at times. We observed instances of this, where students used hot glue guns and cardboard to assemble something in a routine, mechanical fashion. Much more commonly, however, we observed a makerly stance, with much tinkering and testing. For instance, in one project, students were asked to make models of Cal-Earth Ecodomes by filling long skinny balloons with sand. They quickly discovered getting sand into the balloons was difficult, and began making tools to assist them in this task. The tools began as paper funnels, but quickly developed. Ivan and his friends dug through trash bins for straws and water bottles and combined these in various ways, resulting in some of the most sophisticated tools. While we don't argue that this activity directly supported content learning, more students chose to participate than we had observed up to this point, in this project.

We define *designerly agency* as the choices students make to frame the problem they are solving. Designerly agency more directly relates to learning. We share vignettes of how Mr. F explained problem framing, and how two senior students differently framed the problem.

Mr. J:	So what we're gonna do right now as a group, is define our problem, alright. We kinda know the whole purpose of what we're trying to do here, but I want everybody to be on the same page, and I could tell you what the problem is, but that doesn't include you guys and more importantly it doesn't give you guys the opportunity to contribute and say, 'No, I think this is the problem,' or 'I think we should word it that way.' So what we need to do, as a group, here, is collaboratively come up with a specific problem that we are trying to address by building these homeless shelters. So someone start shouting something out. What's the problem that we are trying to fix right now? What are we trying to solve?
Benjamin:	I'm just guessing here, but homelessness.
Mr. J:	Homelessness. Alright. So are we trying to solve homelessness, in general?
Benjamin:	No, we're trying to help them.

A couple weeks later, Mr. F asked Andre to describe the project to a new student. Benjamin joined in.

Benjamin:	This project's basically oriented around homeless people and how, how we're gonna help them, and, uh, right now, um, we've just been—we went to a—an interview with them and talked to him and got to know him, a bit of understanding, a bit of what—how their everyday life is.
Andre:	What's their needs and stuff, I mean//
Benjamin:	//What's their needs.
Andre:	The project's name is actually called Waste Land II, so we are, we, um, we also rely on, also, the—what's available to them on the streets, to give 'em ideas of what to make shelters of to stay warm, stay safe at night. […]
Benjamin:	It's most definitely a interesting project and we, we're all —we are gonna help someone, so we're trying to do this, so. It's interesting.

We see both students expressing interest in the project. Benjamin framed the problem generally—helping people who are homeless, and Andre framed the problem specifically—designing temporary shelters from found materials. These framings led them to make different choices about what information to seek.

Conclusions, discussion, and implications

We found students who speak English at home and who reported higher levels of agency scored higher on a standardized math assessment. It is promising that students making decisions, even ones they are not happy with, can predict higher math achievement. Qualitative analysis afforded an opportunity to detail the kinds of agency endemic to this school. While the set is not intended to be exhaustive, we see it as useful for learning scientists as they go about viewing data from less affluent and privileged settings. We do not argue the set generalizes broadly, but rather, that "attending to both learning and development through a cultural lens" (Lee, Spencer, & Harpalani, 2003, p. 6) is particularly important for learning scientists working with marginalized students; it is easy to miss indicators of engagement that fall outside our worldviews. We found traditional markers of engagement can mask the ways students choose to engage in content delivery, decisions students make about making can serve as a point of entry for learning, and decisions students make about designing can provide meaningful, extended learning opportunities.

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Acknowledgments

Exploring Middle School Students' Science Learning and Discourse in Physical and Virtual Labs

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Abstract: This study compared middle school students' science learning and discourse patterns in physical and virtual labs. Students in virtual labs had significantly higher learning gains than students in the physical labs on a pre and post-test content knowledge test. To understand the difference in learning gains, we analyzed the discourse of the students and teacher as they worked in groups during the labs. We found three main categories of discourse: conceptual talk, task-based talk, and teacher scaffolding. Our analysis of discourse showed that students in the virtual group engaged in more conceptual talk than the physical group, while the physical group had more task-based talk. We also found the teacher provided more conceptual scaffolding during virtual labs than physical labs.

Introduction

Despite the increased interest in researching the differential benefits and limitations of physical and virtual labs, there have been conflicting results about which mode of experimentation better supports students' science learning. Some studies have found that virtual labs better supported students' learning (e.g., Pyatt & Sims, 2012; Zacharia, Olympiou, & Papaevripidou, 2008), while others have found that physical labs helped students to learn more (e.g., Marshall & Young, 2006; Smith & Puntambekar, 2010). Other studies have indicated that there were no significant differences in students' learning from physical versus virtual labs (e.g., Pyatt & Sims, 2012; Zacharia & Olympiou, 2011). In this study, we explored how physical and virtual labs might influence students' science learning and students' and teacher's discourse in middle school science classes.

There is evidence that physical and virtual labs support students' learning in different ways. For example, virtual labs can combine multiple representations, possibly facilitating a deeper understanding of underlying concepts and providing visualizations of processes that cannot be seen during a physical experiment (Ainsworth, 2006). Virtual labs may support learning by offloading error-prone calculations and eliminating measurement error, leading to "cleaner" data, allowing students to explore conditions, such as zero friction or gravity (Zacharia & Anderson, 2003) and to run multiple trials under different conditions and explore variety of ideas in a shorter period of time. Alternatively, even though setting up and conducting physical labs can be time consuming, many researchers assert that manipulating real materials and receiving haptic feedback is essential for learning. According to theories of embodied cognition, conceptual processing is influenced by our movements, bodily states, and use of physical manipulatives cognition (e.g., Glenberg, Brown, & Levin, 2007). Yet, there are many unanswered questions about the learning benefits of physical and virtual experimentation in fostering deep learning of science concepts. To date, most studies have compared students' science conceptual learning via pre and post-tests, and only a few studies have examined classroom discourse to understand how students and teachers interacted when engaging in physical or virtual experiments (e.g, Zacharia & de Jong, 2014; Marshall & Young, 2006). We propose that a full examination of discourse patterns generated by students and teachers during physical and virtual labs will help us better understand the unique affordance of each type of lab. Our research questions for the study were: 1) Does participation in physical versus virtual experimentation result in different learning gains for middle school science students? and 2) Does engagement in physical versus virtual experimentation promote different kinds of discourse? If so, what are the differences?

Methods

Participants and instructional context

Forty-one 6th graders from two science classes, taught by the same teacher, at a Mid-Western middle school in 2015 participated in this study. Students in both classes were engaged in a design-based science curriculum to learn about inclined planes and pulleys (Puntambekar, Stylianou, & Goldstein, 2007). Each class was randomly assigned into one of two conditions: 1) Physical Labs (PL) (N = 19), 2) Virtual Labs (VL) (N = 22).

Sequence of the learning

In both the PL and VL conditions, students: 1) took the pre-test, 2) engaged in research and experiments about pulley, 3) engaged in research and experiments about the inclined plane, and then 4) took a post-test. The pulley and inclined plane units were taught back-to-back. Both units focused on how simple machines can help reduce the force needed to lift an object by increasing mechanical advantage. Students also learned about other concepts, such as potential energy and friction. In PLs students learned about simple machines by setting up and using real pulleys and inclined planes. Students also needed to do calculations to determine values of their dependent variables such as potential energy, ideal mechanical advantage, and actual mechanical advantage. In the VLs students did the same experiments virtually. VL students also explored additional pulley configurations, such as movable and quadruple compound pulleys and carried out idealized experiments with no friction.

Data sources and analysis

Pre and post test measures

The pre test and post test were identical. The test was composed of 21 multiple choice questions and assessed students' knowledge of physics concepts related to pulleys and inclined planes. Student earned one point for each correct answer. The maximum score was 21 points.

Analysis of group discourse

To answer if there were differences between the students' talk while performing physical versus virtual labs, we analyzed the discourse of a subset of five student groups: three from PL conditions and two from VL conditions. There were three to four students in each group. This subset was chosen because we had audio recordings for two pulley and one inclined plane experiment/s for all groups. We segmented the transcripts by turns of talk as the unit of analysis which was multiply coded. There were 2,819 total turns of talk when combining all transcripts. To see if engagement in the PL versus VL condition promoted different discourse patterns, we developed a coding scheme. We inductively identified four macro categories of discourse that the students and the teacher were engaged in during the labs (see Table 1). Our code development was influenced also by Zacharia and de Jong's (2014) work, who found that students doing physical labs often engaged in more procedural versus conceptual talk. Two coders independently coded 25% of the transcripts. An inter-rater reliability of approximately 96% was established after resolving disagreements through discussion. The remainder of the transcripts were coded separately by the same coders.

Table 1: Discourse codes and examples

Macro Category	Micro Code and Definition
Conceptual	**Science Questions:** questions about science relationships or connections to the real world
	Science Explanation: explaining science concepts and relationships or evaluating / making sense of data
	Science Predictions / Patterns: predicting how changing variables affects others / seeing patterns in data
Task-Based	**Reporting and Calculating:** talk about calculating or writing data into charts
	Setting up experiments: talk about manipulating tools, running trials, and the progress of the lab
	Fact Based Questions: questions about how to proceed with lab
Not Applicable	**Not Applicable:** Off task or inaudible
Teacher Scaffolding Talk	**Conceptual Scaffolding:** encouraging students to think about the science concepts and relationships
	Task-Based Scaffolding: helping student to complete tasks, not the science

Findings

Comparison of students' learning gains in physical and virtual conditions

To answer our first research question, we conducted a Mann-Whitney U test to see if there were differences in the learning gains of students in the PL and VL conditions. To calculate learning gains, we divided the actual gain each student made by the total possible gain he or she could have made from pre to post-test. We found that there was a statistically significant difference in the learning gains made by the students in the PL versus VL conditions; Students in the VL condition made significantly greater learning gains than in the PL condition, $z = -2.395$, $p < 0.05$, VL mean rank = 25.82 (55% average learning gain), PL mean rank = 16.84 (36% average learning gain).

Examination of the differences in discourse between physical and virtual conditions

To better understand what may have influenced VL students' significantly higher learning gains, we compared the discourse that occurred in groups by condition. Out of the total 2,819 total turns of talk in all transcripts, we removed 1,164 turns of talk that had been coded as '*not applicable*'. Of the remaining 1,655 turns of talk, 901 were students' and 57 were the teacher's. We then calculated the proportion of students' talk in each macro and micro coding category. To do so, we divided the frequency of each type of talk students were engaged in by the total number of students' turns of talk by condition. For the analysis of teacher's scaffolding, we divided the frequency of the teacher's turns of talk in each category by the total number of teacher's turn of talk during each condition. Due to the number of statistical comparisons conducted, we used a Bonferroni correction for multiple comparisons to minimize Type I error. This means that all significant results (*) were based on a $p < .0005$ significance level.

Results from the chi-squared test on our macro codes showed that students in the VL condition had a significantly higher proportion of conceptual talk (0.12) than the students in PL conditions (0.04) ($z = 5.0847*$). In terms of task-based talk, we found that students in the PL conditions had a significantly higher proportion of task-based talk (0.96) than those in the VL condition (0.88) ($z = -5.0659*$). These results indicated that even though students in both conditions were engaged in more task-based talk, the students in the VL condition were engaged in significantly more conceptual talk than the students in the PL condition.

For our chi-squared analysis of the conceptual talk micro codes, we found that students in VL condition had a significantly higher proportion of science explanation talk (0.06) and science predictions and patterns talk (0.05) than the students in PL condition (0.03 ($z = 2.8226*$) and 0.01 ($z = 3.9527*$), respectively). No statistically significant difference was found between the proportions of science questions asked. For the task-based micro-codes, we found statistically significant differences between the proportions of talk by condition. Students in the PL condition had a significantly higher proportion of talk related to reporting and calculating (0.41) than students in the VL condition (0.20) ($z = -9.1231*$). On the other hand, we found that students in the VL condition had a significantly higher proportion of talk related to setting-up experiments (0.41) as compared to those in the PL condition (0.34) ($z = 2.9384*$). No significant difference in the proportion of fact-based questions asked was found between conditions. These results indicated that students in the VL condition had a significantly higher proportion of talk discussing science ideas, making predictions and looking at patterns in data, and discussing setting up experiments than the PL students. Alternatively, the students in the PL condition spent a greater proportion of their talk on reporting and calculating.

Finally, we ran a chi-squared test of homogeneity of proportions to analyze the teachers' scaffolding talk and found the teacher was engaged in a greater proportion of conceptual scaffolding when working with the VL students (0.33) than PL students (0.04) ($z = 4.6458*$). In terms of task-based scaffolding, the teacher was engaged in a greater proportion of task-based scaffolding talk with the PL students (0.96) than with VL students (0.67) ($z = -4.6458*$).

Conclusions and implications

The goals of our study were: 1) to examine and compare the effects of virtual and physical labs on students' learning gains and 2) to examine students' and teacher's discourse to shed light on how the context of learning in the different conditions may have influenced science learning. In term of our first question, we found that students in the VL condition had significantly higher learning gains than the students in the PL condition. This finding is in line with prior studies showing that students who participated in virtual labs did better than those who participated in physical ones (such as, Pyatt & Sims, 2012; Zacharia, et.al., 2008). For our second research question, we identified two major categories of talk: conceptual and task-based talk. Our discourse analysis showed that VL students had a greater proportion of conceptual talk than those in PLs. Students in the PL condition had a significantly higher proportion of task-based talk. These findings align with Zacharia and de Jong's (2014) analysis that found that students in physical conditions talked more about procedural aspects of labs, rather than building conceptual understanding. It is possible that the process-oriented problems in physical labs restricted students from developing better conceptual understanding. These findings helped us understand how discourse factors may have caused different learning gains of students in the two conditions.

To further tease out the differences between the types of talk *students* in each condition were engaged in, we created micro-coding categories. For conceptual talk, students in the VLs had a significantly higher proportion of science explanations and talk about science predictions and patterns, than PL students. In terms of task-based talk, we found that students in the VL group had a significantly higher proportion of discourse related to setting up experiments, while students in PLs had a significantly higher proportion of talk about reporting and calculating. Even though VL students were engaged in more talk about setting up experiments, the simulation provided outputs for dependent variables and students did not need to take so much time for doing calculations.

Thus, they had more time to engage in science talk such as making sense of data, identifying patterns, explaining, and making predictions.

In terms of the teacher's talk, we identified that the *teacher*'s scaffolding discourse differed between the two conditions. The teacher had a significantly higher proportion of conceptual scaffolding during the VL condition. It may be the case that in the VL condition the teacher could address students' conceptual learning needs as he did not need to help students set up physical materials. This may also be why the students in the virtual labs had a higher proportion of conceptual talk than the students in the physical labs. Thus, not only were the students in the PLs less able to explore conceptual ideas due to setting up materials and doing calculations, when compared to VL students, they also received almost no conceptual scaffolding to help them to think about the science concepts and relationships. So in addition to all of the benefits of using virtual labs, students in the VL condition also had more time to process and think about the data they were collecting, and received more conceptual scaffolding from the teacher. These findings are in contrast with Marshall and Young's (2006) study, which reported that undergraduate students had difficulty processing information from a simulation. However, these differences might be explained by the fact that undergraduate students may have an easier time negotiating and setting up physical materials than sixth graders.

Our study contributes to the literature by identifying and elaborating on students' learning processes and discourse patterns. We developed codes to characterize students' and the teacher's discourse and systematically examined classroom discourse with a mixed-methods approach, which provided a richer understanding of the learning process. Our results indicated that teacher's scaffolding seems to be influenced by the context of learning and the needs of the students. Our findings suggest that teachers should be reflective about their practice to ensure that conceptual scaffolding is always provided to students, no matter the type of lab. Since our results are based on a small sample of students from only two classes and one teacher, replication of this study in a larger setting with more teachers would help improve the power and strengthen the validity of our claims. We suggest that studies in this area should move beyond only examining students' learning on content-based tests. A more detailed account of how different forms of experimentation influence students' learning and discourse is necessary to extract commonalities across different studies.

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Acknowledgments

Iterative Curricular Design of Collaborative Infographics for Science Literacy in Informal Learning Spaces

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Abstract: This short report describes the design and implementation of a two year, iterative curriculum developed to promote science literacies through the creation of news infographics in an informal learning environment. Paid, high school student interns were recruited to identify an issue of personal and social relevance and create infographics that visually represented and communicated the science behind their topic. After several cycles of peer and editorial review, these infographics could be published in an online newsmagazine. Three cycles of data journalism activity with distinct participation and activity structures are described, with considerations of the affordances and constraints of each cycle.

Keywords: STEM literacy, data visualization, designed learning environments, informal learning spaces

Introduction and purpose

The central research question of this two-year study asks, "How can the collaborative critique and construction of infographics using cyberlearning technologies be organized around data journalism practices in learning communities to foster high school students' science and data literacy?" After conducting background research considering how experts make sense of published science infographics (Polman et al, 2015) our team designed and implemented two science infographic learning spaces for high school age students. The learning environment we concentrate our attention on here consisted of a small group of students (approximately ten) who were employed as student interns at a Mid-Western university in the Unites States. These high school interns were paid employees tasked with designing, creating, submitting for review, editing, and ultimately publishing science news infographics of their own choosing. Over the two years that this data journalism internship occurred, we identify three distinct cycles demarcated by specific lessons plans, expectations of students, technological scaffolding, instructor and editor involvement, and ultimately infographic artifacts published by the students. We concluded that though each cycle has particular affordances and constraints, later cycles proved most effective at enabling students to thoroughly engage, digest, and make relevant complex scientific data through the creation of publishable infographics. This short article offers reflections on the iterative design and implementation of this curriculum, with some considerations for future directions

Perspective/Theoretical framework

We frame our review and analysis of the data journalism internship in consideration of a framework of "contextualizing science in life" (Polman, 2012). Each cycle of the intern infographic curriculum began with students making personal connections to science data in their own lives and expanded towards broader social relevance and communication of complex information to the public. The diverse backgrounds and prior trajectories of identification interns bring to the site greatly inform and validate this engagement (Polman, 2012). In this sense, student interns were positioned not just as learners, rather they were active practitioners and conveyors of complex science knowledge (Wenger, 1998). As these paid interns were treated as employees, they entered into and helped define a community of practice (Lave and Wenger, 1991). Through their active participation, independent work, and multiple cycles of peer feedback, student interns helped create and define an informal space where they worked (Polman et al, 2014). These interns had the opportunity to increase their statistical literacy through the use of large scientific data sets (Hammerman, 2009).

Methods and data sources

Our method is an in depth case study of the high school data journalism internship that occurred 2012-2014. Primary data consist of lesson plans, research team meeting minutes, film and activity logs of student work time, student time sheets, multiple drafts and feedback of infographics produced, interviews with students and facilitators, and final infographic products. While this data collected in the 2012-2014 period provides the primary

sources for the research and findings, we situate this information in consideration of the ongoing work currently (2015-2016) being continued by the research and development team, as much of the present trajectory is informed by the findings of the earlier period.

Results

While reports of prior and future cycles are presented elsewhere (Polman et al, 2014) this report highlights the salient findings of a program designed specifically as an informal educational space for out of school student interns.

At the start of this research, the extent with which the infographic internship had definitive stages was unclear, nor had the internship facilitators determined a specific sequence of stages in advance. Only after reviewing the evolving curriculum, student generated work, and facilitator objectives did our team recognize that certain emergent themes and design iterations of the science data journalism curriculum occurred in a chronologically distinct pattern. Cycle 1 occurred March 2013-July 2013. The instructional components of this cycle focused on infographic familiarity, literacy, and deconstruction. The ten participating interns were treated as employees of the university and were under contract to be paid for their work only after the successful editorial review and publication of an infographic. Instruction came in the form of explicit lessons, graphic design workshops, and 1:1 student coaching. Students were invited to pick any science infographic topic that was of personal relevance to them. As such, the student interns were personally invested in their projects, yet the research topics frequently lacked existing valid scientific research, accessible quantitative data, or trustworthy sources. See Figure 1 for an example.

Figure 1. This infographic illustrates the theme of personal relevance in Cycle 1.
The author of this infographic was considering using hair relaxer.

In response to the success of incorporating personally relevant topics and the challenges regarding finding data witnessed in Cycle 1, Cycle 2 (July 2013-January 2014) thematically focused on appropriate topic selection, utilizing data, and contextualizing scientific information. Most interns returned for Cycle 2 and four new interns joined the project. In Cycle 2, an emphasis on data collection and analysis was paramount and design that had some narrative flow was encouraged. Interns could still choose a topic, though they were required to draw data specifically from scientific or academic journals. Facilitators of the project spent less time on direct instruction and focused more on appropriate framing of topics, 1:1 coaching, and project design. Peer to peer and editor feedback of infographics occurred regularly prior to publication. Near the end of Cycle 2, a curriculum design chart was developed by the facilitators to capture the overall flow of the updated infographic creation cycle (see Figure 2).
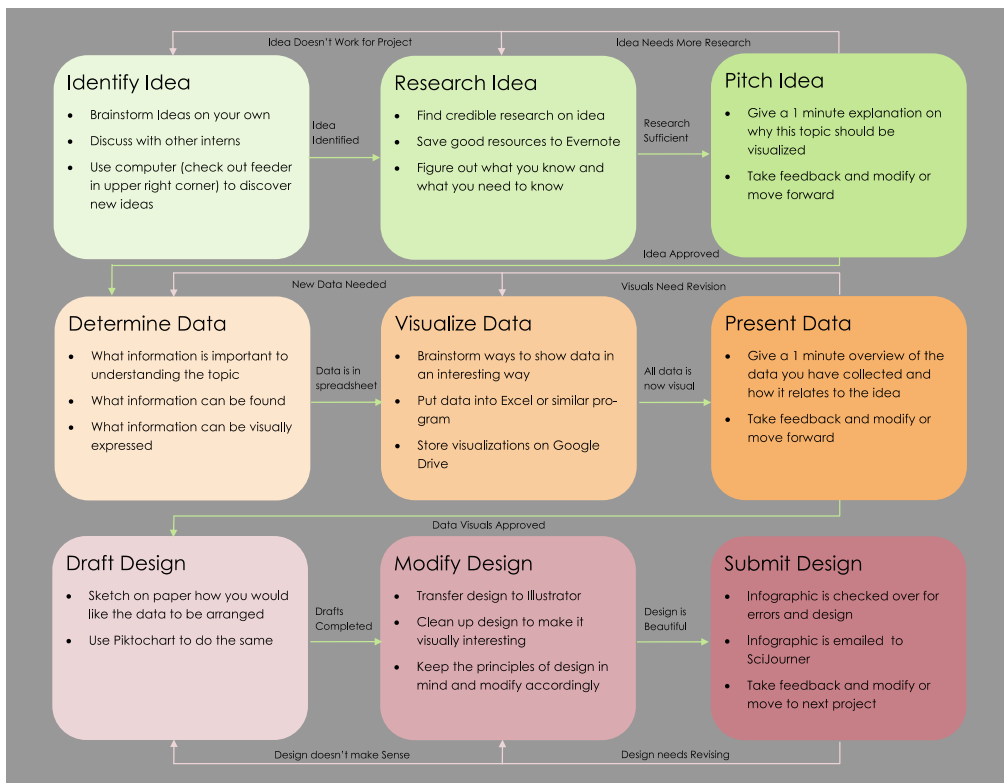
Figure 2. Infographic Curriculum Chart, Cycle 2.

Cycle 3 (January 2014-October 2014) had a more specific emphasis on quantitative information, data hygiene, scale, fair presentation of data, and telling a visual story to viewers of the infographic. In this iteration of the project, interns were still free to pick a specific topic of interest, though the topic needed to be within the broad field of 'agriculture.' The design of this cycle continued to follow the curriculum diagram outlined in Cycle 2. Facilitators placed an increased emphasis on design and presentation with outcome-oriented objectives related to publishing legitimate, usable, scientific scholarly artifacts to be made available to the public. As in the other cycles, final products would be published on an online science news magazine and infographic archive.

Near the end of this research funding cycle the project was approved for extended and ongoing support to continue the high school infographic internship. As facilitators of the field site move forward the key findings regarding infographic literacy, data mining & analysis, topic selection, appropriate feedback, intended audience, and personal and social relevance will continue to inform the future cycles of curriculum design. These lessons provided a foundation for a week-long professional development in June 2015 for other educators to implement these activities in their own classrooms and curricula. Our team continues to collaborate with a variety of teachers in formal and informal learning spaces to advance this work and consider iterative design principles to meet the needs of a diverse range of students.
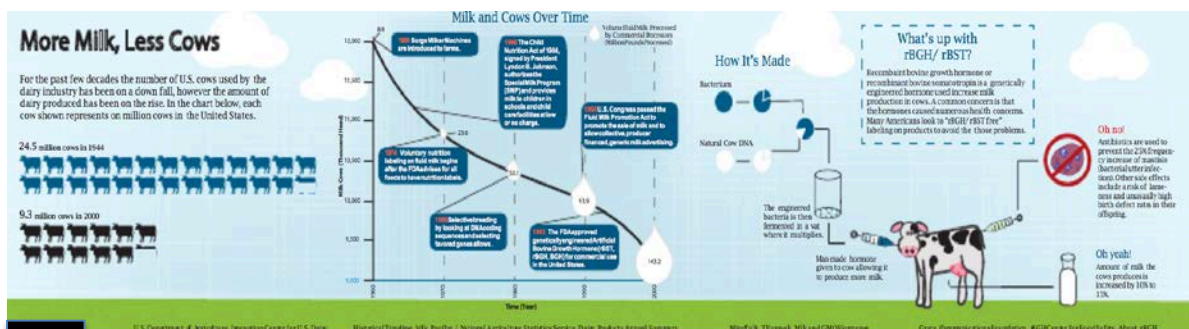
Figure 3. This infographic illustrates the storyline approach with consideration of scale.

Significance

This study offers a contribution to educational scholarship regarding science literacy, the invitation for young people to meaningfully engage with quantitative or statistical data, and the personal and social relevance of scientific topics to young people. This infographic project engages multi-modal components of STEM by exploring science topics utilizing computer software technology, through iterative design stages to illustrate scientific concepts and mathematical relations. Specifically, this research demonstrates the affordances and constraints of various scaffolding and intervention in an out of school learning environment geared at scientific literacy in young people through the design of infographics. These findings highlight specific practices and strategies to engage a diverse range of students in scientifically meaningful discourse and invite them to identify with science, at least in terms of life relevance. This report details specific strategies that work based on multiple iterations of evidence based practice and design. These strategies may be readily exported and tailored to other contexts and learning environments. Further, this work provides groundwork for a future trajectory of similar curricula with an increased focus on personal life relevance and daily engagement with science, offering multi-media outlets for student voice, accessibility and ownership of STEM data, and increased student agency through scientific competencies. Such objectives are already in focus as our team advances this work in our next stage of research and development, and has informed subsequent teacher trainings.

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Exploring African-American Middle-School Girls' Perceptions of Themselves as Game Designers

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Abstract: Computational algorithmic thinking (CAT) is the ability to design, implement, and assess the implementation of algorithms to solve a range of problems. Supporting Computational Algorithmic Thinking (SCAT) is a longitudinal project that explores the development of CAT capabilities by guiding African-American middle school girls through the iterative game design cycle, resulting in a set of complex games around broad themes. This paper explores African-American middle school girls' (called SCAT Scholars) perspectives of their SCAT experience and perceptions of themselves as game designers.

Introduction

Computational algorithmic thinking (CAT) is the ability to design, implement, and assess the implementation of algorithms to solve a range of problems. CAT makes explicit a critical aspect of computational thinking through its focus of understanding how learners identify and understand a problem, articulate an algorithm or set of algorithms in the form of a solution to the problem, and evaluate the solution based on some set of criteria. CAT focuses specifically on how the human, as computing agent, designs, implements, and assesses an algorithm (or an "abstraction of a step-by-step procedure for taking input and producing some desired output") or set of algorithms to solve a problem. CAT is focused on the algorithms designed, adapted, implemented, and discarded by the human (as computing agent) on the journey toward choosing the "right" abstractions. (Wing, 2008; Thomas, 2008). CAT is an important scaffolded on-ramp as students develop more advanced CT capabilities and apply CT to solve problems that are more constrained and require greater and greater expertise. CAT lies at the heart of Computer Science, which is defined as "the study of algorithms" (Schneider & Gersting, 2010). CAT embodies the ability to think critically and creatively to solve problems and has applicability in a range of areas from Computer Science to cooking to music (ITSTE-NETS, 2007; Polya, 1973; Wing, 2006; Wing, 2010).

SCAT is a longitudinal between-subjects research project exploring how African-American middle-school girls develop CAT capabilities over time in the context of game design (Thomas, 2014). SCAT is also a free enrichment program designed to expose middle-school girls to game design. The goals are: 1) to explore the development of CAT capabilities over three years in African-American middle-school girls as they engage in iterative game design, and 2) to increase the awareness of participants to the broad applicability of CAT across a number of industries and career paths. Spanning three years, participants, called SCAT Scholars, develop CAT capabilities as they engage in the game design cycle to design more and more complex games. SCAT Scholars begin the program the summer prior to their 6th grade year and continue through their 8th grade year. They engage in 3 types of activities each year (called a SCAT Season): 1) a two-week intensive game design summer experience; 2) twelve technical workshops where Scholars implement the games they have designed using visual and programming languages (e.g., SCRATCH, App Inventor) in preparation for submission to national game design competitions (e.g., National STEM Video Game Challenge, Verizon Innovation App Challenge); and 3) field trips where Scholars learn about applications of CAT in different industries and careers. This paper aims to explore the following research question: *How does participating in SCAT impact Scholars' perceptions of themselves as game designers?* We begin to address our research question by examining the individual end-of-season questionnaires collected over the course of two years (or Seasons) of the SCAT project.

Background

The iterative game design lifecycle involves several phases, which are also iterative (Fullerton, et. al, 2004). During brainstorming, Scholars generate many ideas for games and present those ideas. Once an idea is selected, paper-and-pencil drawings are created, called storyboards, that include demo artwork. Playtesting is next, which involves bringing actual players from the target user group in and observing them as they play the game in real time, getting feedback about the game experience to inform the design of the game (Fullerton, et. al., 2004; DiSalvo, et al., 2009). Next, Scholars create a playable physical prototype using paper-and-pencil and/or craft materials. Then, a rough software prototype is created which models some aspect(s) of core gameplay followed

by more playtesting. Next comes creating the design document, which outlines every aspect of the game and how it will function followed by implementing the game with playtesting throughout implementation. Finally, quality assurance testing is done with continued playtesting. At any point in the game design cycle, revisiting previous phases may be required.

SCAT learning environment

The facilitator plays a major role in the development of Scholars' CAT capabilities in the SCAT learning environment as she serves first as the primary modeler and then as a just-in-time coach (Collins, Brown & Newman, 1989). In addition, the facilitator leads and supports discussions that help Scholars as they think through their designs, helps them make connections across dyad experiences and problems as they design and implement their games, and models the kinds of questions Scholars should be asking themselves and their peers as they develop algorithms for their game designs, move through the iterative game design cycle, and reflect on their use of CAT (Koschmann, Kelson, Feltovich & Barrows, 1996). As Scholars work in small groups of two on their game designs, she walks from group to group asking them questions about their designs, helping them identify problems and issues, illustrating for them how to use the Design Notebook and other tools and resources provided to them to help them design their games, and serving as a sounding board for dyads as they design.

Although the facilitator is a critical component to the SCAT learning environment, she cannot be with every group or individual all the time. To help overcome that limitation and to help Scholars develop more expert CAT capabilities, the Design Notebook has been created to coach Scholars as they engage in CAT through game design. The Design Notebook has been integrated into SCAT activities, affording Scholars multiple opportunities to develop CAT capabilities while working individually and collaboratively in small groups. The Design Notebook contains paper-and-pencil based tools that coach groups and individuals in the ways cognitive apprenticeship suggests (Collins, Brown & Newman 1989; Puntembekar & Kolodner, 1998) by using a system of scaffolds (Owensby, 2006; Thomas, 2008). Each scaffold in the system supports groups and individuals in a particular way and addresses a particular difficulty that learners may face when engaging in complex cognitive skills, processes, and capabilities like designing an experiment, interpreting and applying the experiences of experts, or engaging in CAT (Owensby, 2006; Thomas, 2008). Given that Scholars will be able to move through the iterative game design cycle at their own pace, those Scholars or small groups who are further along in the game design cycle scaffold dyads who are not as far along (Vygotsky, 1978; Roschelle, 1996; Owensby, 2006; Thomas, 2008; Palincsar & Brown, 1984). In addition, different Scholars bring different perspectives to the dyad, which contributes to greater understanding by the small group as they work.

Methods

Setting and participants

This research takes place at a small women's liberal arts college in the Southeastern United States. Each Season (which runs from June or July through the following May), Scholars participate in the three activities described earlier: a two-week summer experience, workshops, and field trips. This paper focuses on data collected across the first two SCAT seasons, which ran from July 2013 – May 2014 and June 2014 – May 2015, respectively. Over these two years, we have worked with a total of twenty-three (23) African-American girls from their 6th grade year (Season 1) through their 7th grade year. Each year, we work with twenty (20) Scholars. We had three new Scholars from Season 1 to Season 2, representing a retention rate of eighty-five percent (85%). Of these 23 SCAT Scholars, ninety-six percent (96%) had never used SCRATCH, and none of the Scholars had ever engaged in the game design cycle in this way to design novel games for social change.

Data collection and analysis

We collected end-of-season questionnaire data at the end of Season 1 as well as Season 2 to explore our research question. The end-of-season questionnaire was designed to provide insights into Scholars' perspectives and feelings about their SCAT experience, their understanding of CAT, their perceptions of themselves as game designers, and the application of concepts or ideas learned in SCAT to other areas of their lives outside of SCAT. We performed content analysis on the questionnaire responses, identifying themes related to Scholars' thoughts about the kinds of algorithms they designed during SCAT, what they liked and disliked about game design, their perceptions of themselves as game designers, and their feelings about their SCAT experience. Three raters analyzed the questionnaire responses independently, identifying themes that emerged from the responses. Then, all of the themes identified independently were discussed and an agreed upon set of themes emerged from the discussion. Then, the same three raters analyzed the responses again using the agreed upon set of themes. Inter-rater reliability was 87%.

Findings

Kinds of algorithms explored during SCAT experience to date

Scholars described creating many different algorithms in their games, not only in terms of the rules and procedures (e.g., "...we created algorithms for the rules and instructions for the proper way to play our game"), but also to implement game functionality in SCRATCH (e.g., "I used the timer for my game, and the coordinates for a character to go to a certain place when the game switches levels", or "Ones that make the character move from one place to another. Also, when the character touches the coins then the coins will go away"). In addition, Scholars also described exploring algorithms during their SCAT experience outside of game design. For example, for a field trip, the Scholars designed and built clocks using wood, a laser cutter, and a clock mechanism (e.g. "I made [a] clock and we had to put [it] together on the computer then got to see how it looked in real life, and I thought that was cool").

What Scholars liked and disliked about game design

Overwhelmingly, Scholars perceived game design as a creative endeavor that was fun and involved problem solving, both in terms of designing and implementing the game (e.g., "I like [game design] because it's fun and allows you to express your imagination to the game that you are designing", "I like that I get to be creative with my game", or "I like doing the game designing because I enjoy having to figure the things out"). All of these aspects of game design (i.e., game design being creative, fun, and involving problem solving) were aspects that thirty-eight percent (38%), thirteen percent (13%), and another thirteen percent (13%), of Scholars reported liking about game design, respectively. However, Scholars (twenty-six percent (26%)) disliked debugging their games and disliked the amount of time it took to design and implement games (seventeen percent (17%)). Scholars also described other aspects of game design they disliked including: having to work hard, not being able to implement as much of their games as they hoped, using SCRATCH for a second year to implement their games, and sitting in front of a computer (nine percent (9%) each).

Scholars' perceptions of themselves as game designers

Throughout Season 1, Scholars learned a lot about not only game design, but also about the practices of game designers. The facilitator often mentioned that the activities they were engaging in were the same as game designers and that they themselves were game designers. However, the end of season evaluation responses revealed that none (0%) of the Scholars saw themselves as game designers. Scholars seemed to suggest that seeing themselves as game designers implied that they wanted to pursue game design as a career (e.g., "…because I just don't think [game design] is the career I want to have…", "I don't see myself as a game designer because I am not a gamer. I am really not into computer games to the point where I want to design them", "I do like how we made the games, but I don't like all the time it took up and that we had to keep redoing everything and have a lot of patience as we were working on a website with a lot of glitches [SCRATCH]. I also did not like the things we were using don't have some of the exact ideas that we had discussed over the summer camp. So, we had to morph our ideas to fit the computer preferences." Many Scholars suggested that, while they thought that game design was fun, at this point in their lives, they viewed game design more as a fun hobby than a future career.

By the end of Season 2, however, thirty-three percent (33%) of Scholars either currently saw themselves as game designers, considered game design as a possible career, or affirmed game design was their career of choice (e.g., "Maybe because I mostly want to go into animation so this would be leading me to that pathway to do what I want to do", "I do see myself as a game designer. I really enjoy creating games and I've learned so much in the SCAT program so I want to continue to learn and create games that other people can enjoy", or "yes, my ideas and creativeness could be useful"). This suggests that some Scholars' are beginning to see, or already see, alignment between game design and their talents, interests, and future career goals. Further, this finding suggests that their SCAT experiences have impacted some of the Scholars' desire to pursue game design as a career.

Scholars also reported applying, sharing, and showcasing the skills, capabilities, and practices they acquired and developed during SCAT to other settings ranging from school (e.g., "We had an assignment in class, and I got to pull up my game", "In school we had to kind of do something like creating a game" or "…when it was the national day of code I showed my math teacher my game and all the code we did") to community organizations like Girl Scouts (e.g., "Yes, me and [my partner] are doing a girl scout competition where we teach girls in elementary school about coding in order to win a trip to California") and other technology focused activities (e.g., "…I shared what I knew to my robotics camp"). Scholars also described teaching their family members about game design (e.g., "I have taught some [of] my family members. I also practice [game design] on my own") as well as the impact that their SCAT experience has had on their own problem solving strategies and practices (e.g., "…[SCAT] may help me to think out my problems to see what is wrong").

Conclusions and implications

This paper describes the SCAT project and explores Scholars' perspectives of their SCAT experience and perceptions of themselves as game designers. Most exciting is the growing shift of Scholars' perceptions of themselves as game designers, as it suggests that Scholars' SCAT experiences are having an impact not only on the development of their CAT capabilities, but also in the way that Scholars view themselves and what they are capable of. However, this shift also suggests that changes in perception that can impact choices can take a long time to occur. In fact, it was only during the second year that this shift began to take place. Learners need to have not only opportunities to acquire and develop skills, capabilities, and practices, but they also need time to reflect on those opportunities and experiences and assess whether and how they connect to their own interest, goals, and aspirations. As we engage in the third and final year of data collection, we will continue to explore shifts in Scholars' CAT capability development as well as their understanding of CAT and the continued impact of the SCAT program on their perceptions of themselves as game designers, problem solvers, and critical thinkers.

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Mauá Project: Citizenship and Environment Educational as Pathway to Critical Thinking and Students' Empowerment

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Abstract: This article aims to present preliminary results of an ongoing research project linking environmental education and citizenship engagement. We will illustrate the actions of the students engaged in the project to draw their classmates' attention to the school and the environmental issues surrounding them. Particularly, we will focus on the particular on a seminar prepared and presented by the students to disclose the results of a survey conducted of all students in the school. Our preliminary findings suggest that citizenship engagement actions in the school provide students with social leadership (empowerment), and that they thus become agents of transformation in the school environment with *a personal responsibility* and *participatory* attitude.

Keywords: environmental education, students engagement, citizenship, generative themes

Introduction

The popular discourse in the media concerning the environment is also present among educators and teachers; however, the relationship between environmental education and civic engagement has yet to be fully explored. Consequently, according to Reis & Oliveira (2014), teachers are striving to incorporate this topic in science classrooms.

This study presents preliminary results of an ongoing research project linking environmental education and citizenship. The objective of this article is to present the project steps taken to date, with emphasis on the collaborative aspects. We will illustrate the endeavors of the students engaged in the project to draw their classmates' attention to the school and the environmental issues surrounding them. The concept of "generative themes" (Freire, 1989) and the conceptions of the good citizens proposed by Westheimer & Kahne (2004) will be used to analyze the actions of those involved in the project.

This article focuses in particular on a seminar prepared and presented by the students to disclose the results of a survey conducted of all students in the school. Our preliminary findings suggest that civic engagement actions in the school provide students with social leadership (empowerment), and that they thus become agents of transformation in the school environment. Thus, environmental education no longer remains only a theory when present in the school's curriculum; it becomes praxis.

The project

The project is referred to as "Citizenship and Environmental Education: Rediscovering the Capabilities of Mauá High School," and it is funded by FAPERJ (Research Support Foundation of the State of Rio de Janeiro) through Public Notice 36/2014 for improvements in public High Schools. The project's primary objective is development of actions, in cooperation with students and teachers, that promote concrete improvements in the school through environmental education and citizenship.

The Mauá High School is located at Anil Beach, Mauá district. The school offers morning, afternoon, and evening classes for middle and high school students. It is small, comprising eight classrooms, a cafeteria, a kitchen, a 35-person auditorium, a library, a staff room, an office, the principal's office, a courtyard, and a large outdoor area. The school is named after the Viscount of Mauá.

Mauá is a district of the city of Magé, which is located in the state of Rio de Janeiro (RJ); the district is named in honor of Irineu Evangelista de Sousa, the Viscount of Mauá, a Brazilian businessman and banker. The city is located on Guanabara Bay. It was historically the main entry point to Rio de Janeiro City, where vessels arriving from Portugal docked. Another of its important historical landmarks is the first railway built in South America, constructed by the Viscount of Mauá. This railway linked the coast to the country's inland areas, passing through the city of Petrópolis, at mountains region of Rio de Janeiro State, and became the gold trail, because of the transportation of gold and other ores coming from all way inland.

Given the surrounding social context, there is considerable opportunity for discussion in the high school regarding the environment. Even before the project started, some initiatives were already in place, such as waste sorting and water quality consideration.

The project team includes three university professors (authors of this paper), who drafted the project and submitted it to FAPERJ; four scholarship Mauá High School students and one volunteer; and three school teachers, two of whom receive grants (the third is a volunteer). The project was submitted to FAPERJ in September 2014 and was approved in December of that same year. The students' scholarships and professors' grants began in May 2015, however, and funding for the project was released in October 2015. We have therefore been conducting the project since August 2014, when we started visits to the school. Notably, the school's principal gave us full support from the outset of the project.

Methodological procedures

Our methodology is based on qualitative research methods according to Erickson (2012), with the social environment and relations among subjects being the objects of analysis. The Freirean perspective is also used in our methodological procedures, as it regards the emergence of generative themes driving our actions. Generative themes, according to Freire (1989), are those extracted from problematization of the practice of students' lives. As a springboard for the teaching and learning process, a generative theme is a methodology based on the dialectical theory of knowledge, because "outside of the quest, outside of the praxis, men cannot be" (p. 66).

Thus, our methodological procedures inform the project's developmental stages. Immersion of the researchers in the school allowed for identification of environmental issues as a generative theme for preparation and submission of the project. Once the team was formed, actions were collectively guided (Freire, 1989) through work meetings, which took place at the school approximately once every two weeks.

Work meetings

The team's work meetings take place at the school on a two-week basis, and began in mid-May 2015. Audio of the meetings is recorded for record-keeping purposes. The recorded conversations, which raise problems and their solutions, as well as the meeting's conflicts and dilemmas are then transcribed, functioning as an instrument of both data collection and group reflection.

Following the Freirean perspective, meetings are characterized by equal rights of speech and opinion, allowing for the emergence of generative themes and the actions resulting therefrom. In this way, two topics were brought up: the source of the school's water, proposed by the teachers; and the need to know what other students thought about the school, proposed by the scholarship students. The team decided to address the second issue, because before the water issue could be proposed as a topic, it had to be recognized as a problem affecting the students (Freire, 1989). In the process of raising awareness, it was necessary to determine what the students thought—that is, what their opinions and perceptions were about the school in which they studied.

The quest to understand what students thought about the problems existing in the school mobilized the team to take the following actions: (a) Drafting of a questionnaire given to the majority of the students, with questions regarding problems found in the school, teaching methods used by teachers, and their students' own motivation to study; (b) Tabulation and organization of data in charts; (c) Presenting the results to all students in the school during a seminar, facilitated by the scholarship students participating in the project; (d) Interviewing the school's teachers about the student questionnaire results (still in drafting stages).

The seminar: A space for citizenship and students' empowerment arousal

Multiple sessions of the seminar were held on October 6, 2015 so that most of the students could participate. The scholarship students were responsible for presenting the data and promoting dialogue with the other students. To explain the subject of the presentation, one of the scholarship students wrote a rap with lyrics describing the objectives of the project and the completed questionnaire presentation. The rap was sung in each session, followed by presentations by the scholarship students, who took turns in showing their classmates the questionnaire's results.

The question "Do you think that teaching at Mauá High School enables critical thinking in students?" caught everyone's attention. During analysis of the questionnaire, it was reported that although students who answered did not know the meaning of critical thinking, the majority nevertheless responded "yes." In the seminar, this issue was reviewed and widely debated. The argument put to their classmates by the scholarship students was that it would be impossible to induce a transformation of reality without critically analyzing it.

We are going to present some of Esther and Robert's point (both scholarship students) about critical thinking during the seminar. At the following table it is possible to see their statements and how they make points to the other students.

Table 1: Esther and Robert's point made during the session of the seminar

Event	Transcription
1 (session 1)	**Esther**: I would like to ask you a question that isn't here at the presentation, but it was in the questionnaire. Do you know what critical thinking is? Someone else knows it? Could someone else give me its definition? **Student 1**: Speak out your own opinion? **Esther**: Yes, it does count! I gonna give an example (...) there was this question " Do you think that teaching at Mauá High School enables critical thinking in students?" What do you think? (...) I would like to hear you guys! [silence] **Student 2**: It is ... when people keep on track to achieve their rights, and so do teachers and students have to be motivated. **Student 3**: It is missing in our classroom **Esther**: Noop! It is missing everywhere! We realize many students run away from this topic (...) but it is very important. We have to apply critical thinking everywhere and every moment (...) For instance, I cannot impose to you my will and you just accept it (...) thus we need to learn to criticize and to claim (...) But remember, to claim it is necessary to be within the compliant.
2 (session 2)	**Esther**: Here [she points to the graphic showed in the projection screen] the of the students responded "yes" [to the same question of event 1), but will the most of students know what was critical sense? [some students say "no"] Why did students respond "yes" then? [silence] Guess or what? **Students**: Lack of interest **Esther**: Lack of interest, what else you think? (...) they didn't answered what they really think, they didn't use their critical thinking (...) **Student 1**: They were manipulated ... **Esther**: Yes! Exactly, you gotta!
3 (session 2)	**Esther**: Now listen up, how about social enviorment, what could critical thinking contribute to you later? **Student 2**: to have own opinion, right? **Esther**: Yeap! What else? **Student 3**: Don't let be manipulated! **Esther**: Let me say this: if nowadays we don't have critical sense to respond this questionnaire, will we have critical think to vote or to claim our rights? [silence] ... no!
4 (session 2)	**Robert**: Hey guys, listen to me, I gonna ask you three questions: do you think Mauá High School needs to change? Please, hands up! ... ok! now... who wanna the school changes? Please, hands up again! ... all right ... so among those who said wanted the changes, who wanna do something to change it? [there some silent moment followed by students comments] **Robert**: Ok! Now, who has already thought to do something? [one or two students say they have] So why didn't you do it? **Student 4**: Because nobody cannot do anything, don't you remember when I was punished [he is talking about something in the past] **Student 5**: None take us seriously since first grade of High School [Note: High School in Brazil has three years 1st to 3rd grade] before I wanted to something, I had this attitude, you know, of change something, but not anymore. (...) **Esther**: I gotta, you try to something but they [administrators] don't let them do it, I gotta! so you need be critical just for these situations (...) but I am hereby to speak up it is possible (...) you gotta have the perseverance, because it is something you gonna use it later. I just say it because I know it is possible [to change].

Discussion and first conclusions

The conceptions of the good citizens proposed by Westheimer & Kahne (2004) can be used to briefly analyze Esther and Robert's discourse during the seminar presentations as well as the whole project. Westheimer & Kahne (2004) defined: *personally responsible* as the responsibility of someone else within the community by working, paying taxes, obeying the laws; *particpatory* the act of leading or organizing events, it is expected this leader knows how government work; *justice-oriented* those who seeks out, critically assesses for social justice.

Thus, Esther's point about the critical sense issue is considered as personally responsible and participatory ways of citizenship act. For instance, at the event 1 when she says "but remember, it is necessary to be within the complaint", she is pointing out to students' personal responsibility to deal with different situations. Event 2 shows her attitude tending to the participatory perspective once she is trying to make other students think about. In other words, she acts like a school leader. Nevertheless, her leadership is more evident at the event 3 when she calls for students' attention about voting. Robert is more around the personally responsible attitude at the event 4, when he asks the three questions. Neither Esther nor Robert had trained or planned to do the presentation with the researchers, which were there for supporting them.

Environmental issue was addressed both in the beginning and in the end of each session. Usually Esther asked to students their opinion about environment. After some students' responses such as "green; water; air; pollution" she turned to social environment, in which their school is part of. At this point, the issues regarding to water and environment were discussed again as a critical perspective. Therefore, the seminar was an important step in the project's development in that the students themselves engaged their classmates in dialogue.

Based on the theory of dialogic action (Freire, 1989) we can see the seminar promoting collaboration, generating themes and perspectives of changing in teaching through empowerment of students. The theory of dialogic action is based on four characteristics: *collaboration*, *unity*, *organization*, and *cultural synthesis*. Collaboration brings subjects together to transform the world: "Subjects meet in cooperation in order to transform the world. Collaboration can only be achieved through communication. Dialogue, as essential communication, must underlie any collaboration" (Freire, 1989, pp. 167-168). Unity must occur in favor of liberation and transformation, a form of exercising collective praxis. Organization "is not only directly linked to unity, but is a natural development of that unity. Accordingly, the leader's pursuit of unity is necessarily also an attempt to organize the people, requiring witness to the fact that the struggle for liberation is a common task" (p. 176). Finally, cultural synthesis is based on the different views of subjects. "Cultural action is always a systematic and deliberate form of action which operates upon the social structure, either with the objective of preserving that structure or of transforming it" (p. 180).

The dialogue established among students reinforced the characteristic of collaboration, particularly regarding to the issue of critical thinking, which became a vehicle for communication among them. The students' speech during the seminar demonstrated characteristics of unity and organization, and the structure of the seminar can be considered a cultural synthesis. For example, the scholarship student who wrote the rap communicated to his peers through the artistic and cultural language of the community in which the school is located. At the same time, the arguments presented by the scholarship students point out a democratic leadership whose definition of critical thinking is a method for communication and transformation.

As our first findings we are able to state the issue about critical think emerged as one of main points in this whole process so far is related to how people act in their own environment, that is, how they are citizens. Thus we point out the lack of any participatory attitude of Mauá High School Students is related to the history of Mauá district. Despite its historical importance, the Mauá district is plagued by environmental pollution, including debris from the bay and from the community, which still lives with a precarious urban infrastructure and a lack of basic sanitation. At the context of the school, students do not understand this situation as a problem. No problem, no conscious about either water quality or other social conditions they have.

In conclusion, in the context of the Mauá High School, environmental education has to foster the critical think as way to make student conscious about their own problem (FREIRE, 1989), as opposed to a curriculum that fails to develop students and teachers' critical thinking ability. Then in our point of view, empowering students means to make them conscious about their own problem, consequently, to push them up to take up higher levels of citizenships.

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Acknowledgments

Exploring Visualization and Tagging to Manage Big Datasets for DBR: A Modest Proposal With Significant Implications

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Abstract: As design-based research (DBR) approaches increase in popularity, there is greater and greater need to invent database management systems that document the designs and phases of DBR projects as meaningful contexts for archival storage of large databanks that such projects create. Such database systems must also support transparent and efficient search and selection of data to enable rapid analysis by design teams as well as collaborative data sharing and analysis by multiple researchers. This paper outlines one system devised by a team of design-based researchers for documenting their research process and organizing their data. Inspired by the hierarchical workflow model suggested by Hackbarth et al. (2010), this approach employs a combination of visual modeling and data tagging to organize and support rapid access and sharing of a large DBR databank.

Keywords: design-based research, data management, workflow

Introduction

Design-based research (DBR), a currently popular research approach in The Learning Sciences, involves the systematic, iterative design of learning environments in authentic contexts with aims to develop both educational innovations and advance theory (Barab & Squire, 2004; Collins, Joseph & Bielaczyc, 2004; The Design-Based Research Collective, 2003). DBR researchers tend to approach their work with a priori research questions, but also collect data broadly, leaving the door open to unanticipated discoveries (e.g. Derry et al, 2010). Despite its promise and appeal, DBR has been the subject of warranted criticisms. Famously, DBR has been criticized for poorly leveraging the vast amounts of data typically collected, resulting in relatively minor findings (e.g., Dede, 2004). One aspect of this problem follows from the requirement that research from each phase of design should thoughtfully inform the next design phase; thus significant, in-depth data analysis should take place between design iterations. Yet an open question is whether and how DBR projects have achieved the capacity to perform rapid processing of vast amounts of data in sufficient depth to inform continuing design phases within reasonable project timeframes.

This paper shares ways of working seldom discussed in The Learning Sciences while inviting deeper examination of important data management issues that follow from using mixed methodologies and broadly collecting data in authentic contexts during iterative DBR. Little scholarship exists that directly addresses issues of how to adequately organize and conceptualize both research and innovation design and management of DBR data. One exception is work reported by Hackbarth, Derry, Eagan & Gressick (2010), who described how workflow concepts could be utilized to communicate the structure of learning-environment designs and organize the data from DBR projects in terms of those designs. A symposium at the 2013 International Conference of the Learning Sciences (Derry et al., 2013), called for development of a cyberinfrastructure for DBR. This panel focused on solutions involving database standards and development of sophisticated data management tools that might be adopted throughout the community.

In this contribution we share one project's approach to data organization and management for DBR that does not require the existence or development of sophisticated visually-based data management tools (although it may be viewed as a logical step in that direction) and thus represents an approach accessible to all researchers, including those who might not have sophisticated database resources or knowledge. Developed in the context of our curriculum design work in middle school biology to help us clarify and share designs and manage large datasets across multiple iterations of design and implementation, our approach aims to make accessible our data, make apparent and transparent our research and intervention designs, and open the door to the possibility of collaborative data and design sharing as well as big data analytics approaches in the future. In pursuing this work, we attempted to consider not only our own needs, but also raise questions about what forms of standardization and generality would be needed to make this approach viable for researchers in various domains and contexts and with a variety of research structures, methods and questions. For example, the approach should be as suitable for researchers designing museum exhibits as it is for those working on middle school curriculum.

In this paper we share the basics of a data management system designed to meet the following criteria:

1) Visually capture key features of the learning-environment design and design changes that occur over multiple iterations of a project.

2) Visually represent the actual time-stamped workflow of activities that occur during and across multiple design iterations.

3) Organize all data collected (video, assessment, observations, team notes, etc.) and artifacts created (curriculum materials, student work, etc.) so that they are "located" within and thus can be understood in the context of the project's workflows and designs.

4) Allow flexible viewing of the project at multiple levels of specificity and flexible search and access to data at various time points and levels of detail.

5) Offer a structure that is both general enough for use across various projects and domains but also provides sufficient standardization to enable data sharing and analysis across domains.

6) Allow for storing and association of analyses (theses, dissertations, intermediate project work) within the context of the data employed for those analyses, in the manner of the Video Mosaic project (Video Mosaic Collaborative, 2010).

Design

An ideal data management system for DBR might include an adaptable, standardized (by the DBR community) interactive, graphical interface connected to a standardized (by the DBR community) relational database, optimized for usability and able to seamlessly facilitate the organization of and rapid access to fully contextualized and annotated data banks with associated analyses. This is the need and solution argued or implied in some previous work (Derry et al., 2013; Hackbarth et al., 2010). Yet our current approach illustrates a much easier solution and shows how any DBR researcher could build and manage a complex dataset working with readily available programs (e.g., Inspiration), meta-data capabilities inherent in various file types widely in use, and query functionality of most computers' operating systems. Our approach has two aspects: Visual Project Representation and associated Data Tagging System. We illustrate the approach in the context of our own work.

Levels of visual representation

We designed a visual representation system that captured the overall structure of the project as well as the smaller, sub-structures that, on the most detailed level, captured the design of the innovation itself. Our project is a large, multi-site, multi-year endeavor. Researchers at the University of Wisconsin at Madison and the University of North Carolina at Chapel Hill are working together to iteratively develop three different curricular units for middle school biology. For ease of explanation here, we restrict our example to the case of one site, although the ideas are easily extensible.

We designed four levels of organization, each with its own visual representation, as shown in Figure 1. Level 0 is our highest level, which orients us to the curricular unit within which we are operating. Level 1 is organized hierarchically below Level 0, and encompasses major Phases of research in the development of each curricular unit. Following that, Level 2 represents Stages of work within each Phase. Finally, Level 3 provides a work-flow representation of the Activities within each Stage. Following Hackbarth et al. (2010), diagrams adapt standard workflow elements to represent inputs, outputs, beginning and ending activity sequences, activities, technologies, participants and participant structures. Further levels could be added to locate analyses as they develop. The number and names of components within this model, as well as the number of levels in the hierarchy, could be adapted to the needs of other projects. The model serves two purposes. The first is to provide a representation to orient researchers and contextualize data within the overall and detailed structure of the project. The second purpose is to provide an organization for the data tagging system, to be discussed next.

Data tagging

Challenges of DBR research include the vast volume of data collected over time and the complexity of that data. There are many different forms and file types (video, audio, field notes, assessments, student artifacts, etc.), which have meaning and purpose only in the context of complex interrelationships they have with one another, with research questions, and with design features and changes made during a project. For example, our research program produces many hours of video data collected by several cameras running simultaneously within one classroom, recording three separate groups of students engaged in collaborative activity. In addition we have lesson plans, curriculum materials of various file types, technology logs, student work artifacts, photos, assessments, teacher and researcher reflective notes and audio recordings from analysis sessions.
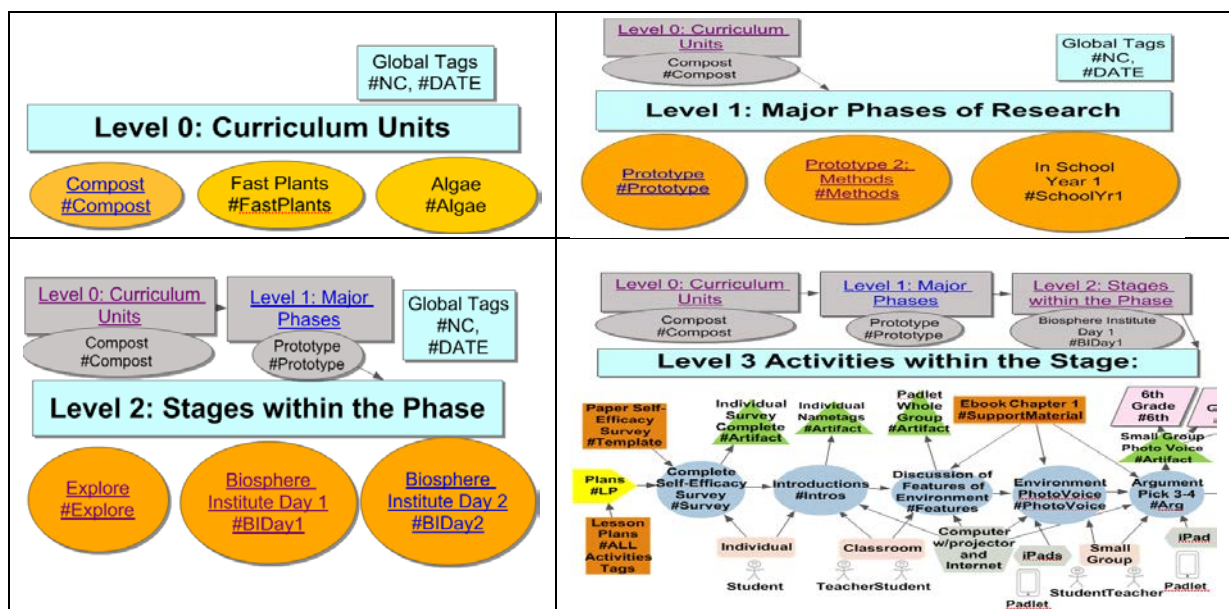
Figure 1. Workflow-Based Visual Representation Sample.

These data forms are typical for DBR projects and our conversations with other researchers indicate that a typical approach to data organization involves the use of various electronic and physical file folder systems, with organizational strategies that are unique to each project and vary widely in structure, quality, and fidelity of implementation. Such systems are difficult to consistently implement even across researchers within a single research team. When using the database to address research questions, projects must crisscross the distributed landscape of their database to locate the specific data required, which must be oriented within both the environmental context (e.g., the classroom and activity) and the context of the project (e.g., the phases of research) in order to be able to appropriately analyze it. Without appropriate organization such search is time-consuming if possible at all. To address these challenges our team devised a system that utilizes the tagging functionality in our files' metadata, based on the visual representation system, as described below:

Tag design
The logic of a tagging system is to provide unique identifiers that can be used alone or in combination in a query to locate data that have certain characteristics. The pound sign (#) in combination with a descriptor (i.e. #Compost), commonly known as a hashtag, has been popularized on social media as a way to index postings on sites like Twitter, Instagram and Facebook so that postings that are thematically related to one another can be located by those interested. Those that post can include one or more hashtags with each post to contribute to any number of online conversations. Inspired by social media hashtagging and in search of a way to label our files with unique identifiers that could be used to sort and filter them, we created all of our file tags in the fashion of hashtags, including first the pound sign (#) then a descriptor that is chosen and used following some basic guidelines that we have developed. Creating tags that begin with the pound sign (i.e. #Prototype), rather than simple key word (i.e. prototype), helps to ensure that tags are unique and will not likely occur naturally within any of our files and erroneously show up in a query. The use of the pound sign to distinguish tags was a convenient extension of familiar social media systems, but any other unique symbol could also be used.

Tag assignment and organization
As discussed above, our visual system is organized around a system of levels and a workflow inspired representation of activities (Figure 1). Tagging is designed to work within this visual system of organization. Each file first receives global tags, which include a location tag, for us #NC, and a date tag (i.e. #5-13-15). From there tags are assigned at each level. Level 0 tag will indicate which curriculum unit the piece of data is associated with (i.e. #Compost). Then a Level 1 tag is applied, which indicates within which phase of research a certain file falls (i.e. #Prototype). Then it is assigned a Level 2 tag, which indicates within which stage that file falls (i.e. #BIDay1). Then the file is tagged based on the appropriate Level 3 tags which typically include activity tags, type-of-data tags and sometimes a group tag. For example, Level 3 tags for a Lesson Plan file for Biosphere Institute Day 1

would include #LP and all of the activity tags for that day (i.e. #Survey, #Intros, #Features, #PhotoVoice, #Arg), because the lesson plan will include information pertinent to all activities of that day. On the other hand a video clip of the 6th grade group's argument task from that same day would include all of the same Global, Level 0, Level 1, and Level 2 tags, but would only include #Arg (activity), #Vid (type of data) and #6th (group indicator) tags for the Level 3 tags. When we query our database with that combination of tags we are able to retrieve a specific video clip. By querying our database with a tag or combination of tags, we can locate specific data, a type of data, or data associated with a specific phase of research or activity. Working together, visual representation and tagging provide a powerful means for data organization and access.

Implications and next steps

Currently our visual representation system in combination with our tagging system allows us quick, flexible access to our data, increasing the speed and efficiency with which we can scan, select and analyze data between design iterations. It provides us with tools for organizing, sharing and communicating about our work amongst ourselves, and with capabilities for sharing both designs and data with other researchers outside our project. By sharing ways of working with data, we hope to inform other researchers about a feasible solution to an important problem that all DBR researchers must grapple with, encourage further conversation about ways of working with the type of "big data" that DBR creates, and contribute to conversations among DBR researchers about data sharing and research collaboration far beyond the scope of what is currently possible. In answering criticism about the large amounts of unused data typically collected in the course of DBR, such systems have the potential to make transparently contextualized data available to multiple researchers, thereby multiplying its usability and the payoff for such resource heavy work.

Moving forward we plan to work to increase the utility and applicability of our design. Working with experts on database creation and management, we aim to explore potential software solutions to make our visual design and data retrieval process more efficient and seamless. We will also consult with other DBR researchers to gain and share insights about other database management solutions and to better understand the possibilities and limitations of our system as currently conceived. Such research may allow us to develop guidelines and a level of standardization for data tagging within the DBR community, further maximizing the collaborative potential and scholarly impact of this innovation.

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Acknowledgements

What Are Crosscutting Concepts in Science? Four Metaphorical Perspectives

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Abstract: To think more productively about the role of crosscutting concepts (CCCs) and how they influence students' three-dimensional science understandings of phenomena, we took a hermeneutic approach to examine the literature and language of the *Next Generation Science Standards* and its supporting documents. Using the perspective of Lakoff and Johnson (2003)'s conceptual metaphors, our analysis identified a set of four metaphorical perspectives – CCCs AS LENSES, CCCs AS BRIDGES, CCCs AS TOOLS, and CCCs AS RULES – that the texts use to describe the role of CCCs in three-dimensional science learning. We discuss the affordances and limitations of each perspective, their implications for instruction and assessment design, and directions for future research.

Introduction

Traditional science instruction has primarily consisted of a series of teaching activities focused around a single core idea. Current reforms in science education are changing that perspective to emphasize three-dimensional understanding of core conceptual ideas in combination, interaction and progression with science practices and crosscutting concepts, in ways that bridge ideas from multiple disciplines across phenomena (Pellegrino, Wilson, Koenig & Beatty, 2014; Roseman, Fortus, Krajcik, & Reiser, 2015). The seven crosscutting concepts (CCCs) in the *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013a) play a particularly important role in this new perspective on learning. In *A Framework for K-12 Science Education* (referred to as the *Framework*), the National Research Council [NRC] (2012) emphasizes these concepts as particularly important and necessary, in that they "help provide students with an organizational framework for connecting knowledge from various disciplines into a coherent and scientifically-based view of the world" (p. 83).

In our efforts to support teachers and developers with designing instruction for three-dimensional learning, however, we have found the CCCs to be the most difficult dimension to discuss and develop shared understanding. The language used to describe the CCC dimension and how it relates to the other two dimensions in the *Framework*, the NGSS, and other supporting documents is generally sparse, ambiguous, and inconsistent. The lack of consistency and details in explaining the CCCs is a contributing factor that has limited our ability to consider ways to effectively support understandings of this important dimension in terms of instruction and curriculum materials. To address this problem, we conducted a hermeneutic analysis of the texts describing CCCs from the *Framework*, NGSS and its appendices, and other supporting and foundational documents. Through this process, we identified four different metaphors used to describe the nature of CCCs. Rather than representations of what the CCCs actually are, we found that these metaphors served a more abstract purpose, in that they are used to describe four different conceptual frameworks for thinking about the role CCCs play in three-dimensional understandings of science.

This paper presents the results of this analysis, describing the affordances and limitations of these four metaphorical perspectives on CCCs. We consider how these different perspectives may help the field better conceptualize and utilize CCCs productively, particularly with respect to instruction and assessment design.

Theoretical framework and methodology

Lakoff & Johnson (2003) define conceptual metaphors as linguistic representations of complex phenomena that make use of language associated with more relatable experiences. For example, one often describes the concept of time using words that we might more readily apply to money: that meeting *wasted* my time; this shortcut will *save* you hours; traffic on the highway *cost* me three hours (Lakoff & Johnson, 2003). These idioms reflect a coherent metaphor, *TIME IS MONEY*, which allows us to think productively about how time is a valued resource with the language usually applied to money, a more tangible resource that people value. In our hermeneutic analysis we focused on how the language around CCCs in the *Framework*, the NGSS appendices (NGSS Lead States, 2013a; 2013b) and other supporting documents reflect different conceptual metaphors.

Our analysis began by examining theses texts for instances where they describe the nature and use of crosscutting concepts through comparison to more tangible phenomena. These instances were flagged and

clustered into nine potentially productive conceptual metaphorical categories. We compared, scrutinized and re-clustered the evidence in this initial categorization scheme against foundational and supplementary documents to further support how the metaphors provided meaningful insights on the CCCs and the interrelation between CCCs, SEPs, and DCIs. This process resulted in a set of four conceptual metaphors for CCCs that operated in ways akin to that of the *TIME IS MONEY* metaphor (Lakoff & Johnson, 2003).

Four metaphorical perspectives for thinking about cross cutting concepts

Metaphor 1: CCCs AS LENSES

Most commonly, the language of the NGSS and related documents conveys the crosscutting concepts through the metaphor of a set of lenses, particularly describing them as a means of observing and seeing salient features of phenomena. For example, the language of the NGSS (NGSS Lead States, 2013b) notes that *Patterns* (one of the seven CCCs) must be "observed" or "noticed." Another crosscutting concept, *Scale, Proportion and Quantity* allows students to see things that are "too small, too large, too fast, or too slow to observe directly." A third, *Cause and Effect,* helps students to "see events" in terms of the internal causal phenomena (NRC, 2012). Sight is an understandably useful experience to ground metaphorical understanding (Lakoff & Johnson, 2003), as many of the goals of science are described as attempting to see the previously unseen (Duschl et al., 2007). We refer to this conceptual metaphor as *CCCs AS LENSES*. This metaphor has a number of affordances for scientific reasoning. When students engage with the CCCs via the *CCCs AS LENSES* metaphor, they consider features of a phenomenon or problem that they may have previously found insignificant. The different CCCs allow analyses of a situation or problem in distinct ways, all of which can be considered legitimate approaches to reasoning about that phenomenon. For example, a problem involving force and motion can be addressed by taking an *Energy and Matter* lens (i.e. focusing on the transfer of energy in the system), or it might also be examined from a *Cause and Effect* lens (i.e. focusing on what forces will cause changes in motion). These perspectives could also be combined to consider both the causal relationship and the transfer of energy within the interaction. Taken together, considering *CCCs AS LENSES* results in students' robust three-dimensional understandings of the relationship between force and motion.

However, real lenses are engineered for a limited set of purposes; one would not expect a pair of glasses to help them observe the structure of a cell nor a microscope to help them read the newspaper. Similarly, *CCCs AS LENSES* suffers from a lack of well-defined transferability amongst disciplines. While several lenses may be useful to solve a particular problem in a discipline, it may not be obvious that the lens has utility in a new context. The *CCCs AS LENSES* metaphor is a productive way of thinking, but understanding the CCCs also requires the ability to see how the same concept is used across several scientific knowledge domains.

Metaphor 2: CCCs AS BRIDGES

To develop sophisticated scientific understanding, it is important for students to recognize the application and transfer of content knowledge between interconnected domains and phenomena. The NGSS and supporting documents use the language of "connections" and "directions" to convey this role of crosscutting concepts in three-dimensional science learning. We labeled the use of this language as reflecting a second metaphor for CCCs, that of *CCCs AS BRIDGES*. For instance, the NGSS states that the crosscutting concept *Cause and Effect* serves to help students understand phenomena A and B in terms of "interactions which connect" the two (NGSS Lead States, 2013b). Similarly, the CCC progression for *Systems and Systems Models* includes that in high school, "students can…simulate the flow of energy, matter, and interactions within and between systems." (NGSS Lead States, 2013b). An example of the utility of understanding the crosscutting concept *Structure and Function* from the *Framework* (NRC, 2012) describes how an engineer's understanding of the role of density in structural design can "lead in turn to an examination of atomic-scale structure" in designing a new bike (NRC, 2012, p. 97). The language of connectivity, transfer, and movement is emblematic of this linguistic image of *CCCs AS BRIDGES*. In this metaphor, students use CCCs to recognize conceptual relationships between phenomena, and as a means for explaining the complexity of a macrosystem in terms of its constituent parts.

However, considering *CCCs AS BRIDGES* is potentially limited in its ability to support understanding relationships between concepts in the ways that scientists do. Given the plethora of potential connections that could exist between phenomena – and without clear criteria for evaluating the efficacy of one connection over another – connections that scientists make may not be seen as productive by students. It is also the nature of "connection" to emphasize similarities over differences. Students using *CCCs AS BRIDGES* may find correspondences between concepts more prominent than non-correspondences, when both are required for developing sophisticated understanding. This metaphor is a powerful means to develop a sense of the transferability and connectivity between concepts, but understanding CCCs also requires one to recognize which connections are productive in explaining and predicting the natural world.

Metaphor 3: CCCs AS TOOLS

Within the *Framework* (NRC, 2012), we identified a third metaphor for understanding the role of CCCs: *CCCs AS TOOLS*. The authors of the *Framework* frequently emphasize a mechanistic approach in which consideration of a CCC helps students leverage existing understanding to produce more sophisticated knowledge. "Crosscutting concepts have value because they provide students with connections and intellectual tools that are related across the differing areas of disciplinary content and can enrich their application of practices and their understanding of core ideas" (NRC, 2012, p. 218). This underscores the value of CCCs in helping students to engage with science and engineering practices in a more meaningful and effective ways. We also found evidence for this third metaphor in the language of the NGSS. For instance, within the description of the CCC *Patterns*, "students progressively build upon this innate ability [to identify patterns] throughout their school experiences" (NGSS Lead States, 2013b). In one performance expectation (HS-PS2-1), students are expected to use their understanding of the CCC *Cause and Effect* to generate the evidence needed to "support an argument that the gravitational force exerted by Earth on objects is directed down." (NGSS Lead States, 2013a). The language of tools, building, and construction is evidence for the mechanistic *CCCs AS TOOLS* metaphor. Just as levers and pulleys provide mechanical advantage in doing physical work, through this metaphor, students gain advantage in using their existing understandings to construct complex explanations and resolve practical problems. In this sense students' understandings of different CCCs operate as cognitive tools (Brown, Collins & Duguid, 1989) that develop meanings through their applied use in different contexts.

While the perspective of *CCCs AS TOOLS* conveys the useful and practical aspects of developing understandings of CCCs, this view does not imply that subsequent use CCCs will be inherently transferable or generalizable. Rather, students' situated expertise with CCCs develops over time, and requires explicit reflection on when, how, and for what kinds of phenomena and problems consideration of the different CCCs are most productive. Additionally, considering *CCCs AS TOOLS* specifically emphasizes the ways that these perspectives leverage students' prior knowledge and understandings to explain phenomena or address problems. However, it is important to keep in mind that students' prior knowledge varies across groups and contexts. This in turn impacts the ways in which different students may be able to use the *CCCs AS TOOLS* and the depth to which they engage with the CCCs in their learning, thus further influencing the extent to which they develop robust three-dimensional science understanding as called for in the NGSS.

Metaphor 4: CCCs AS RULES of the Game

In the NGSS and supporting documents, the process of developing robust three-dimensional understanding of science is at times portrayed as a form of playing an epistemic game (Collins & Ferguson, 1993) which has both goals (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014) and rules of engagement (Collins & Ferguson, 1993). From this perspective the CCCs play the role of *CCCs AS RULES* for this epistemic game. In this sense, understanding and using different CCCs to learn science can provide order and structure to students' potential understandings of a complex (and often chaotic) world. For example, applying the CCC *Patterns* can make "order…emerge from chaos" (NGSS Lead States, 2013b) by creatively organizing students' thoughts about phenomena (NRC, 2012). Likewise, when describing CCCs such as *Structure and Function*, the NGSS states that understanding how CCCs serve rule-like functions helps constrain investigations "in order to know what properties [and aspects]…are relevant" (NGSS Lead States, 2013b). Rules help to establish a shared language to communicate acceptable behavior within a game (Walton, 1990); CCCs are able to serve a similar purpose from this point of view. An early step in developing sophistication for understanding the CCC *Scale, Proportion, and Quantity* is for students to recognize that there exists "standard units" of measurement agreed upon by the scientific community (NGSS Lead States, 2013b). The existence of rules helps to justify representational systems (Walton, 1990), including scientific investigations (Duschl, et al., 2007), to ensure that outcome of the game leads to understandings (Collins & Ferguson, 1993) of the natural world as aimed for in the NGSS.

In describing the three dimensional learning framework, Duschl (2008) points out how students must develop epistemic understanding of "[the] specialized ways of talking, writing, and representing phenomena" (p. 275) in the sciences. Considering *CCCs AS RULES* enables students to use CCCs as a way to organize their learning in light of these epistemic practices of science (NRC, 2012). The epistemic focus of this metaphor is a strength but also a challenge. In science classrooms, students often develop epistemologies of their practices that are distinct from what scientists do, often with unproductive results (Sandoval, 2005). Likewise, students using *CCCs AS RULES* may consider the CCCs as rules for the classroom, but not necessarily for the scientific community. Ideally, students' understanding of the CCCs should enable them to develop formal and practical epistemologies about their science knowledge similar to those of practicing scientists (Duschl et al., 2007; NRC, 2012; Sandoval, 2005).

Implications for teaching and assessment

Our discussion of these four metaphorical perspectives on CCCs identified from the framing documents of the NGSS illustrates how students' understanding of the role of CCCs as part of three-dimensional learning can vary, and the implications that these different understandings of CCCs may have on their resulting science understanding. We believe these metaphorical perspectives will be helpful for teachers and curriculum designers who are using the NGSS and supporting documents to craft instruction. For example, teachers can direct students to the *CCCs AS LENSES* metaphor to suggest novel ways of looking at situations using several different CCCs, and help students recognize that each lens results in a different way of considering the problem. When bundling several NGSS performance expectations (Krajcik, et al., 2014) into a coherent unit, designers may utilize the *CCCs AS BRIDGES* metaphor as a way to assist both students and teachers to connect content ideas that address different parts of a bigger problem or context. Alternatively, teachers may use the *CCCs AS TOOLS* perspective to leverage students' understandings of simple systems to construct more complex explanations that are useful for a greater set of problems or contexts. Teachers may consider the *CCCs AS RULES* metaphor as a way to foster the idea that science is socially constructed, as rules of games are often socially negotiated (Walton, 1990), or as criteria to limit the scope of an investigation (Collins & Ferguson, 1993) in ways that are most productive for answering particular questions.

Each of these metaphorical perspectives conveys a different story about the CCCs. The story that students develop about CCCs will frame their views of how the crosscutting concepts fit within their three dimensional understanding of phenomena. Like any other representation, the set of four linguistic representations of CCC understanding have both affordances and constraints. No single representation is as useful in isolation as they are together. Thus the aim is for students, like scientists, to not draw distinctions between the different ways of understanding CCCs. Instead, these combined perspectives on CCCs are one aspect of more encompassing gestalt system that is greater than the sum of its parts.

The NGSS challenges not only existing curriculum materials (Roseman, et al., 2015), but also the nature, role, and features of existing assessments (Pellegrino, et al., 2014). These metaphorical perspectives on CCCs in three-dimensional learning can also provide guidance for considering the design of assessments. They provide a means for conceptualizing how evidence of the role of CCCs can be made visible in student activities and products, and may be used to inform understanding of learning progressions and instructional decision-making. Our future research and design efforts will focus on these goals.

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Situating *Deep Multimodal* Data on Game-Based STEM Learning

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Abstract: As STEM embedded games become more prevalent in classrooms, the need for teachers and researchers to understand the ways in which students learn in these complex environments increases. This paper describes a multimodal datastream approach to understanding student learning in an informal game-embedded curriculum. Through a multi-stream approach, we have more information on what students are using and how they are improving, which in preliminary analyses, proves to be more complex than one might think. Importance of multiple data streams in analyzing complex learning environments and future directions for more complex analyses are discussed.

Introduction

Video games are gaining attention for their potential to engage learners' interests in STEM and achieve learning outcomes (Mayo, 2009), yet they also present an exciting opportunity to extract formative information about how learning occurs through these digital devices. Games have the capability to amass a large body of click-stream data representing the actions, choices, successes, and failures of the player without disrupting the engagement that games evoke. Games often incorporate effective learning strategies such as scaffolding, adapting challenges to learning curves, engaging curiosity, and situating content in interactive environments with social surroundings. In addition, gameplay can mimic the scientific process of discovery, as players develop hypotheses and experiment with different actions. These similarities to other educational processes have not gone unnoticed by educators, who have produced educational video games to capitalize on the inquiry-based nature of gaming (Barab, Gresalfi, & Ingram-Goble, 2010).

Although players of commercial games have been known to engage in STEM practices outside of more traditional learning contexts (e.g., Steinkuehler & Duncan, 2008; Martinez-Garza, 2015), many STEM games are just one component of a larger learning curriculum. Incorporating STEM games into a larger learning curriculum allows players to work in groups, reflect upon their gameplay with their peers, and draw connections between their gameplay and the broader scientific content. This approach also allows researchers of scientific games to collect more targeted data regarding players' learning.

The data that researchers in this area collect is as varied as the STEM games themselves. At the very least, researchers may collect pre to post data on domain content knowledge in order to determine whether their scientific games lead to learning gains (e.g., Papastergiou, 2009; Coller & Scott, 2009). Participants' attitudes regarding the game are also frequently captured. Less frequently captured, however, is the connection between participants' in-game behaviors and their learning gains. Even more rarely captured is the relationship between learning gains, in-game behaviors, and participant discourse surrounding the game. In this paper, we explore these multiple data streams in order to form a more cohesive understanding of our participants' experience with our STEM game.

Methods

Intervention: Game-a-Palooza

To examine how participants engage in science learning through games, we developed a spring break camp for middle school students dubbed *Game-a-Palooza* (GaP). During the 5-day event, participants cycled through three educational video game sessions including our intervention of interest, titled *Virulent*. *Virulent* is a strategy game for ages nine and up designed for players to learn about viral replication and how the body's immune system reacts to infection. In the game, players control the 'Raven Virus', a fictional virus with biology-content-relevant characteristics. Players move through levels by infecting host cells, stealing precious resources, and fighting the immune system with viral proteins. To further engage the participants, *Virulent* sessions were framed in a role-playing activity.

The activity started with a video from actors roleplaying as a mock Center for Disease Control (CDC) team asking for help to stop the Raven Virus epidemic. Participants were grouped into twelve research teams of 3-4 players each. Participants were also given the opportunity to switch teams after assignment to allow friends or siblings to participate together, as the camp was designed to be both fun and informal. Across our groupings, we collected large and diverse amounts of data including clickstream gameplay data, discourse on and around the game, and pre- and post-assessments. On the first day, teams investigated preliminary recommendations on how to stop the Raven virus from spreading by observing the virus and the cells' defenses in the first few levels. The second day focused more on gameplay and constructing a visual model of virus and cell interactions. Teams updated their models and recorded presentations of their models to be sent to the mock-CDC for review on the third day. The fourth day consisted of cohort presentations to other groups and ended with an "emergency" call from the CDC reporting that they too have become infected by the Raven virus. On the last day, teams were presented three hypothetical solutions for stopping the Raven virus. These were based on articles from journals, media, and textbooks that were adapted to the content. Teams presented their findings to the cohort, debated, and voted for which solution to use.

Virulent acted as a source of click-stream data for our research by logging all game actions, their context, the use of an in-game almanac. The almanac provided a virtual directory where players could look up definitions and corresponding pictures of every cell part and virus component found in the game, allowing players to connect biological knowledge with game knowledge.

Data collection

Pre and post assessments
Before and after the *Virulent* curriculum, all participants completed identical short assessments measuring their knowledge about cellular biology and virology. Items measuring content knowledge included 8 multiple choice questions, 2 open response prompts, and a model with cell parts to label. Open response items were scored using a rubric from 0 to 1 based on accuracy and completeness of response. An aggregate score of *Biological knowledge* was calculated from these items for each participant. Participants were allowed to leave responses blank, as the assessment was not treated as a formal test. As such, biology knowledge scores were calculated as a proportion of correct responses out of the number of questions attempted.

Talk data
We collected a complete stream of discourse (verbal) data via a lavalier audio recorder worn by every student on their name badge. In addition, we video-recorded the classroom presentations of models of the virus and debate of proposed solutions for the epidemic. Lastly, we conducted daily interviews with the participant teacher.

Click-stream data
For each participant across all five 90-minute sessions, we recorded a complete stream of in-game telemetry data via our backend data framework: the Assessment Data Aggregator for Game Environments ADAGE (Owen & Halverson, 2014). ADAGE is a tool for logging and tagging clickstream data for every event within the game, allowing for analysis of player-actions to triangulate those in-game play patterns against other external measures.

Hypotheses
Intuitively, we expected our primary data streams to align. Increased use of the almanac to look up cell parts and virus components should lead to increased use of biology terminology in discourse and increased biology content knowledge post assessment scores. We would also expect that increases in group engagement (measured via amount of general talk) would align with increases in post assessments scores, as we anticipate player engagement to track with learning outcomes.

Results

Pre and post assessment
Forty-three players completed a pre and post assessment. Overall, players showed limited knowledge of cell biology and virology facts on the pretest (M = .233, SD = .207). After the intervention, players attempted a similar proportion of posttest items (M = .753, SD = .325), but their accuracy on those attempts was much higher (M = .491, SD = .213), indicating a significant increase in biology and virology knowledge over the 5 day intervention ($t(42)$ = 5.47, p < .05).
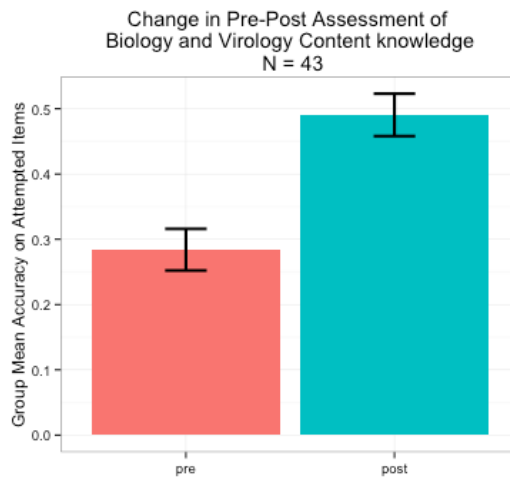
Figure 1. Aggregate change in biology knowledge

Discourse data

To assess how discourse changed between the participants in the *Virulent* sessions, we began by looking at the length of words used as a rough proxy for sophistication of talk (after Flesch, 1948), and examined how this discourse changed across the five days within each research team. As seen in *Figure 3(a)*, research teams conversed with longer words on average during the fourth and fifth days of the intervention. Group means across all five days show that word length increased for all participants. Looking across the five day curriculum in *Figure 2(a)*, we see differences in how the curriculum may have prompted more discussion, though the data are skewed by one outlier group. During the penultimate day, participants used more biology vocabulary words as a percentage of their total spoken words.

(a)   (b)
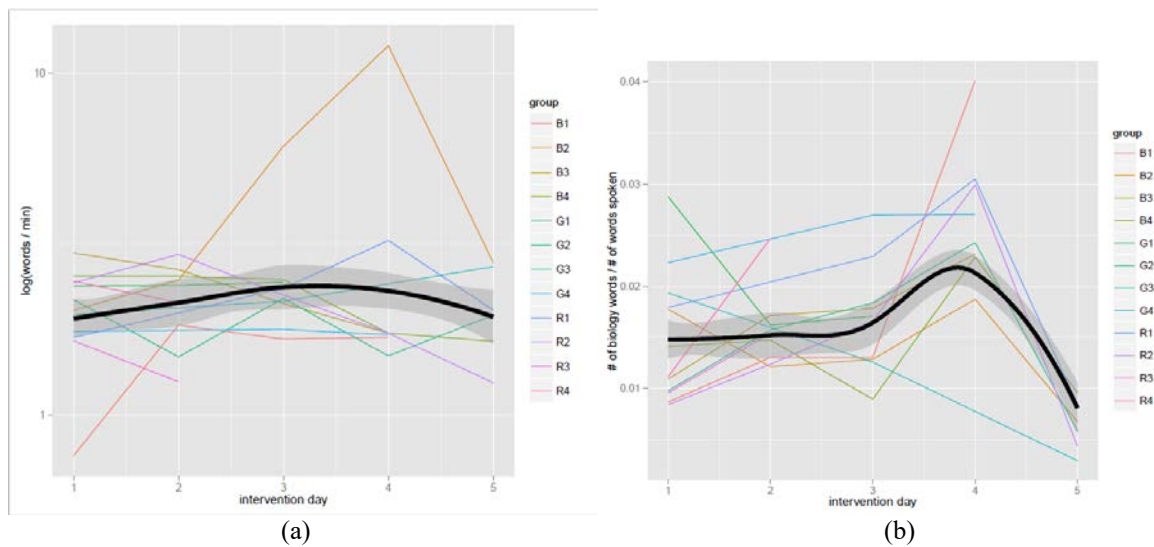
Figure 2. Overall use of biology terminology (a) and proportional use of biology words (b).
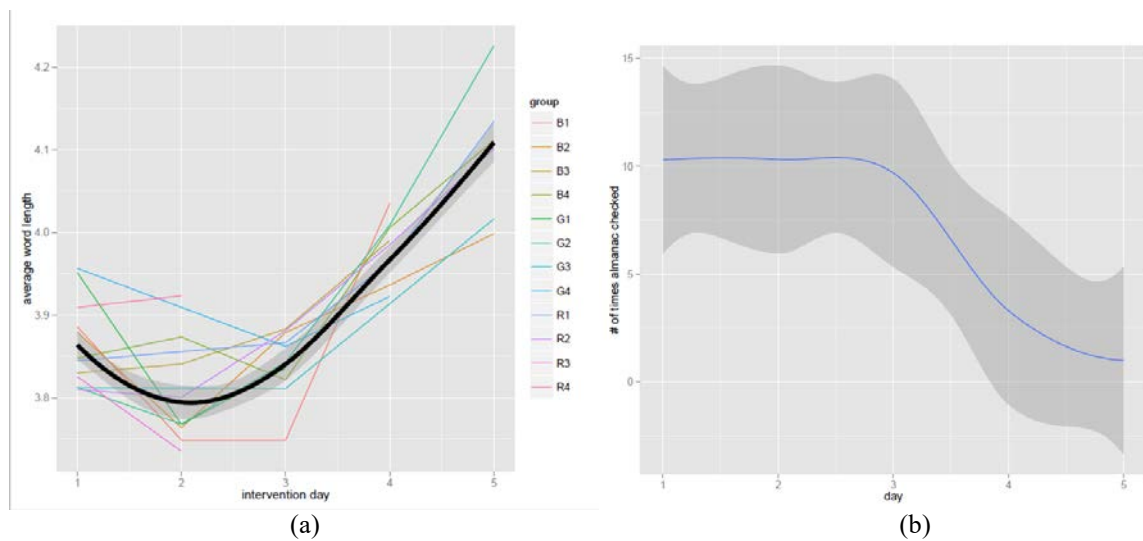
Figure 3. Average word length (a) and almanac usage (b).

Discussion

These preliminary analyses of multiple adjacent data streams in a scaffolded informal learning environment show the importance of each data source for understanding how students construct knowledge in a complex space. Being able to contrast game play behaviors with talk audio as well as pre/post assessment provides a granularity in the data that shows a larger picture of student development and understanding. However, from these data, we find patterns that are much more complex than expected. While we do not see the expected correlations between data streams, we still find that virology-specific knowledge increased 18% across participants, and participants used more complex language towards the end of the camp. This suggests that students did learn the embedded biology content but this was not captured in ways we would expect. Perhaps the increase in biology terminology in discourse and decrease in almanac usage suggest a transition away from reliance on the almanac as players become more familiar with the content. The complexity of the data and the importance of the individual differences only became clear as a result of triangulating seemingly clear findings; this is a challenge to the field.

Future research

Several lines of inquiry are currently being pursued to further complexify our data, including: participant interest, biology content gains, argumentation, model making, play patterns viewed through telemetry, differences in formal and informal play, and motivational factors. The multiple data streams from this study allow us to merge audio, video, artifacts and clickstream data in ways that will provide a more complete, albeit more complicated narrative.

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Designing for Effective Collaborative Learning in High-Needs Rural Classrooms

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Abstract: Orchestrating collaborative meaning making in classrooms can present a significant challenge to teachers, in particular, for teachers in under-resourced middle schools in rural areas. This paper reports on issues that arose during a prototype implementation of a biology curriculum for middle school students, which resulted the design of collaborative scripts supported by technology that aid teachers in advancing student thinking.

Keywords: collaboration, technology, classroom orchestration, macro- & micro-scripting

Introduction

The context of our research is Biosphere, a federally funded Design-Based Research (DBR) project that is a collaborative effort between the University of Wisconsin at Madison and the University of North Carolina at Chapel Hill. We are developing an inquiry biology curriculum that focuses on local sustainability issues and is suitable for under-resourced middle schools in rural areas within the United States. Our work is grounded in foundational research on collaborative meaning making, which has shown that technology-mediated building and sharing of collaborative knowledge advances both group and individual development (Scardamalia & Bereiter, 2014). However, productive technology-infused collaborative learning environments cannot happen without proper design and support (Kaendler, et al., 2014; King, 1997).

Orchestrating collaborative meaning making in classrooms can present a significant challenge for even the most experienced teachers. Orchestration of collaborative learning in classrooms has been conceptualized in terms of macro-scripts and micro-scripts (Kaendler et al., 2014; King, 1997). *Macro-scripts* are specific activity plans for teachers and students, designed in accordance with research and theory, which help ensure productive collaborative interactions (Kaendler et al., 2014). *Micro-scripts*, in contrast, are small repeatable routines that represent possible just-in-time principled pedagogical interventions that a teacher can use in situations where students need additional guidance for collaborative learning. Kaendler et al. (2014) examined the nature of effective macro- and micro-scripting in classroom settings and conceptualized the teacher competencies necessary for effective collaborative learning as including these scripting skills.

The Kaendler et al. model, while providing useful inspiration for our work, assumes developing high levels of teacher competence and significant planning and reflection time for implementation. These requirements are not easily met at our research site, a rural, under-resourced middle school. As is typical in many under-resourced schools, our site school has rates of teacher turnover and levels of uncertified or under certified teaching staff. Therefore, our challenge is to shift the major scripting demands put forth in the work of Kaendler et al. (2014) away from teachers and onto the curriculum itself, thus reducing the teachers' "orchestration load" (Dillenbourg, 2013). The design solutions we are exploring necessarily rely on technologies that are accessible, affordable, and usable to help even underprepared teachers orchestrate technology-mediated collaborative learning and teaching in high-needs rural schools. This is a substantial challenge and the theoretical contributions of our work pertain to adapting previous work on scripting and orchestration of collaborative learning for high-needs contexts.

Theoretical framework

Collaborative script theory provides a useful framework for the evaluation and design of collaborative learning environments (Fischer et al., 2013; Kaendler et al., 2014). Fischer and colleagues propose seven principles of their script theory. For example, the sixth principle based in Vygotsky's (1978) zone of proximal development states that external scripts can allow learners to engage in collaborative learning at a level beyond what they are able to successfully accomplish on their own in the beginning of a collaborative process. External collaborative scripts are gradually faded to foster development of student internal collaborative scripts (Fischer et al., 2013).

Knowledge Building as conceptualized by Scardamalia & Bereiter (2014) provides additional theoretical inspiration for conceptualizing our technology-based design solutions in which small group knowledge is disseminated among the class using a platform conducive of open sharing of content information. This theory

disseminated among the class using a platform conducive of open sharing of content information. This theory argues that technology-mediated building and sharing of collaborative knowledge advances both group and individual development (Scardamalia & Bereiter, 2014).

Methods

Our over-arching method was *Design Based Research* (DBR), an iterative process that incorporates cycles of data collection, analysis and reflection to inform design of educational innovations and develop theory (McKenney & Reeves, 2012; Easterday et al., 2014). The Easterday et al. model has six iterative phases: Focus, Understand, Define, Conceive, Build, and Test. The research reported here is based on data obtained from implementing a prototype of Unit 1 in the Biosphere curriculum, which will have three units. In Unit 1 students design a composting bioreactor to anchor science inquiry. Although we followed all the six stages of DBR within this prototype study, this study was our first experience with the school and population and thus represented the early Focus through Conceive phases in relation to the larger, multi-year DBR project. This prototype study informed design of the version of Unit 1 now being implemented in classrooms. The study also served as a baseline since the curriculum at this stage provided minimal scripting and orchestration, allowing us to judge baseline capabilities of teachers and students.

Data were collected during Biosphere Institute (BI), an 8-day after school program with two follow-up summer sessions. The participating school was a STEM middle school in a rural and economically disadvantaged county in the Southeast staffed largely by teachers with alternative training such as Teach for America. The school purports to focus on project-based learning and the principal believed that teachers and students were experienced with collaborative learning. Student volunteers were solicited through letters sent to parents by the principal. Eighteen students agreed to participate. Participants were racially diverse and included students from grades 6-8.

The BI took place mostly in a large science classroom. During seatwork students were grouped by grade level (6-8) around rectangular tables, although projects took them into other parts of the school grounds. Each day students engaged in a collaborative task with their small groups, but recorded reflections and results on personal iPads that contained curriculum materials, which prompted students to answer specific questions about their inquiries. Examples of small group inquiry activities in Unit 1 of the Biosphere curriculum include collecting evidence about the school environment, conducting inquiries into how much trash the school creates, designing a composting bioreactor, and creating a composting plan for the school. The learning goals include development of complex biology knowledge related to energy cycles.

The primary analytic method was video recording and analysis following guidelines for video research in the learning sciences (Derry et al., 2010). Each student group was video recorded with a researcher taking field notes. A camera in the corner of the room recorded whole class activities and the instructor.

Data from the 6th and 8th grade groups were analyzed to afford contrasting cases of how the curriculum worked at two different developmental levels. Two researchers repeatedly reviewed the 6th and 8th grade videos. From these viewings researchers compiled 90 minutes of clip samples that ranged from 10-15 minutes in length and enabled study of group behaviors during collaborative tasks. These selections were transcribed and examined in depth through a process that involved repeated interaction analysis of discourse (IA; Jordan and Henderson, 1995) by the authors. Recordings of the IA sessions and session notes were analyzed in accordance with conversation analysis conventions with no coding applied.

Summary of main findings

Video analyses of the prototype implementation uncovered numerous problems we could address with improved macro- and micro-scripting. The issues students experienced in small group learning included:

- Frequent off-task behavior and argument digressions.
- Failure to transfer individual ideas expressed on iPads to group collaborative thinking.
- Focus on individual technology that hindered group collaboration.
- Extensive overlapping talk and significant difficulty sharing and exchanging ideas in ways that included all voices.
- Focus on task completion at the expense of deep thinking.
- Failure to utilize argumentation scripts for target content, despite evidence of internal argumentation scripts.

Concurrently, we observed that teachers experienced the following in orchestrating and facilitating student groups:

- Missed opportunities for supporting and interrogating student thinking.

- Inability to scaffold student argumentation with science content.
- Failure to recognize all students' contributions.
- Focus on affective engagement rather than student thinking.
- Sub-optimal orchestration of classroom technology infrastructure.

Design of macro- and micro-scripting support

Based on the prototype study the design solution addressing these issues has four components: Macro-script for students, macro-scripts for teachers, micro-scripts for teachers, and technology support for collaborative orchestration.

Student macro-script

To assist students with group collaboration a Think, Collaborate, Share (TCS) script was designed into the curriculum materials and teacher guides to provide students with individual thinking time, time to share their ideas with their small group, and then an opportunity to discuss with the whole class. Additionally, collaborative roles such as *Scribe, Speaker,* and *Task Minder* were incorporated into curriculum and teacher materials.

Teacher macro-script

Teachers will be trained and curriculum materials will be structured to support the 3R orchestration cycle, a macro-script based on Fong et al.'s (2015) observations of experienced teachers orchestrating collaborative learning. The 3R orchestration cycle consists of teachers regularly calling a whole-class plenary session to Reflect (pause group work to study and evaluate what is going on), Refocus (redirecting work if necessary), and finally Release (return students to working collaboratively in groups). Teachers will enact the cycle multiple times during collaborative group work, using the technology system described below, to help them gain insight into and ability to interrogate and push student thinking.

Technology support for collaborative orchestration

The 3R cycle will be facilitated by technology through the use of Linoboard, a free collaborative tool where teachers can create space for students to share ideas. The Linoboard interface will be on the small group iPads as well as projected onto a screen that will facilitate whole class discussion. After students collaborate in their small group, the Scribe in each group will be responsible for constructing the group's note on the Linoboard platform. Once submitted, the note is shared with the whole class thus offering a space for knowledge distribution on the class level. Students can view all submissions via their iPad or the projection on the larger class screen. The teacher can use this technology feature to highlight group ideas and have the Sharer respond and Reflect upon the work that has been completed. The Linoboard interface provides teachers a platform to Refocus student thinking before Releasing them to edit and refine their thinking. Once released students will use the Linoboard feature that allows them edit their previously made note to incorporate new ideas from the Reflect phase of the 3R cycle. The collaborative space also serves as a platform for teachers to view all group work and indicates which groups need micro-scripting for further refinement of ideas.

Teacher micro-scripts

Teachers will be trained when and how to use several micro-scripts designed to address specific student issues observed in our study. Curricular materials designed for the teacher will provide suggestions and reminders for when they should be used. An example of one micro-script is re-voicing (Alozie, Moje, & Krajcik, 2010), which can be implemented during the Reflect phase of the 3R cycle. Re-voicing is a technique for facilitating collaboration by reflecting back and restating the contributions of students in order to clarify and draw attention to specific ideas. The teacher can use re-voicing to highlight student contributions and to aid in Refocusing the class or individual groups. Other micro-scripts will require teachers to be vigilant for certain thinking issues, such as evidence of common misconceptions related to understanding ecosystems and energy cycles or for evidence of argument digressions. Materials and training will supply micro-scripts for particular problems that are expected to occur.

Concluding comments and next steps

The problem we address is how to orchestrate effective collaborative science learning in under-resourced rural schools characterized by high-needs students, high teacher turnover, and a high percentage of under-prepared teachers. We make use of theories and research on collaborative learning from The Learning Sciences to create educative curriculum materials designed to support orchestration of effective collaborative learning through the

coordinated use of macro-scripts for students, macro-scripts and micro-scripts for teachers, and supportive collaborative technologies for students and teachers. Our design challenge is to discover ways to embed these within student and teacher curricular materials so that, as a coordinated system, they will function effectively as scaffolding that might be faded over time, building on and enhancing both the collaborative scripts of students, and the orchestration capabilities of teachers. An added dimension of our challenge is our choice to rely on technologies, that are accessible, affordable and usable. An example is the sharing platform, Linoboard, which is free, web-based, and allows many different devices to use it simultaneously to create a seamless, collaborative, knowledge building-learning environment. Important research questions for our work include understanding the extent to which effective collaborative knowledge building can be supported and acquired through curricular design inspired by research and theories from The Learning Sciences but that does not depend on long-term development of skilled teachers. We also seek to understand how these theories must be modified in service to this population. Our next curricular implementation that includes design changes described in this contribution will help shed light on these questions as we examine the evidence on whether our designs have the intended impacts on students' and teachers' collaborative knowledge building processes.

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Acknowledgements

Supporting Calculus Learning Through "Smooth" Covariation

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Abstract: Calculus is a passport for STEM-related careers. In response, this thought experiment analyzes the current nature and state of pre-calculus, drawing attention to a common and problematic approach to teaching function. I argue that this approach to function fosters a kind of thinking that conflicts with the kind of thinking required for a conceptual understanding of calculus and suggest one way to support teaching and learning of pre-calculus is to highlight the features of function that are fundamental to calculus. I suggest that this can be done through carefully constructed mathematical tasks and present a framework for task development.

Keywords: covariation, pre-calculus, calculus, smooth function

Introduction

According to the Bureau of Labor Statistics in May 2014, the ten highest annual mean salaries by occupation are in STEM-related fields. STEM-related fields are the most lucrative and fastest growing fields in the United States and many other countries. Candidates who are eligible for STEM-related careers usually have a strong mathematics background. Unfortunately, for many students, calculus serves as a "gatekeeper" on the education path that qualifies students for a STEM-related career. In turn, students are marginalized from the career and economic opportunities afforded by STEM-related careers.

As the global economy continues to advance, education must evolve and advance with it. In the United States, there are not enough students taking pre-calculus courses in high school. In 2009, 35% of high school graduates took pre-calculus (National Center for Education Statistics, 2015). Given the economic affordances of calculus, these numbers are alarming. I argue that the problem of calculus stems from the nature of teaching and learning calculus.

Similar conclusions have been drawn about algebra. In response, researchers have argued for *early algebra*, which they distinguish from algebra early. Early algebra is a way of thinking that spans elementary and middle school mathematics. It involves building on traditional elementary curriculum by generalizing, representing, justifying, and reasoning with mathematical structure and relationships (e.g., Blanton, Levi, Crites, & Dougherty, 2011; Carpenter, Franke, & Levi, 2003; Kaput, 2008; Kaput, Carraher & Blanton, 2008). I argue that the first step to addressing the problem of calculus is to re-conceptualize pre-calculus as a longitudinal strand of thinking that extends through middle and high school mathematics. That is, pre-calculus should involve building on algebra by recognizing and articulating change and continuity in functional relationships. This is a new and evolving idea, but I suggest one way to support this approach to teaching and learning pre-calculus is to highlight the features of function that are fundamental to calculus, and I argue that this entails characterizing functions as "smooth," continuous, covarying quantities.

Despite the many algebra and pre-calculus curricula that use function as a central concept, most high school and freshman college students have a weak understanding of function, which is an important concept for studying advanced mathematics (Carlson, 1998; Carlson, Jacobs, Coe, Larsen & Hsu, 2002; Monk & Nemirovsky, 1994; Thompson, 1994a). I argue that the way that function is approached in teaching is conveyed through curriculum and instruction, including problems and activities. Moreover, the instructional approach fosters conceptualizing function a certain way.

Often problems about or approaches to teaching functions promote thinking about variation at whole number intervals. For instance, a problem that reinforces this approach might ask students to graph a given function. To solve this problem, students will likely plot and connect points. While students may correctly graph the function, it is unlikely that they are making sense of how one quantity changes as the other quantity changes or attending to the change that occurs between the whole number intervals. In other words, students are unlikely to interpret the function in terms of two continuous covarying quantities because a task similar to the one described draws attention to specific *x*- and *y*-values, in turn, portraying function as discrete and variables as static. This approach is commonly used by students in U.S. schools (Leinhardt, Zaslavky, & Stein, 1990).

Despite its prevalence, researchers believe this approach over emphasizes procedural and localized skills (Bell & Janvier, 1981; Leinhardt, Zaslavky, & Stein, 1990). Furthermore, I argue it overlooks the characteristics of function that are essential to finding a derivative because it avoids the continuous features of function, and furthermore highlights the discrete features of function. That is, this approach steers away from a view of function that supports learning in calculus, and fosters a kind of thinking that conflicts with the kind of thinking required

for a conceptual understanding of calculus. In response, this thought experiment explores a covariational approach to function that promotes learning in calculus and suggests characteristics of mathematical tasks that support the approach. Specifically, I propose a framework for constructing mathematical tasks based on two arguments. First, "smooth" covariational reasoning fosters a productive disposition towards calculus. Second, the mental action of coordinating covarying, nonnumeric quantities promotes "smooth" covariational reasoning. In the following section, I justify these arguments. Then, I present the proposed framework. Finally, I share the theoretical and practical implications of these ideas.

Fostering a productive disposition towards calculus

Covariational reasoning is the mental action of "coordinating two varying quantities while attending to the ways in which they change in relation to each other" (Carlson et al., 2002, p. 354). A covariational approach to function is critical to students' understanding of numerous secondary mathematics topics including quadratic relationships (Ellis, 2011), exponential relationships (Castillo-Garsow, 2012; Confrey & Smith, 1995), trigonometric relationships (Moore, 2010; Moore & Carlson, 2012), rate of change (Carlson et al., 2002; Thompson, 1994a), the conceptual ideas of calculus (Thompson, 1994b), and differential equations (Rasmussen, 2001).

By definition, reasoning covariationally necessitates reasoning about covarying quantities in terms of rate of change. Hence, prior research has shown that reasoning covariationally results in thinking about change in a sophisticated way that is constructive to understanding calculus (Johnson, 2012). Moreover, the covariational approach to function draws attention to specific types of change (e.g. difference, accumulation and rotation), and distinguishing types of change is critical for expressing and describing a relationship between two quantities in multiple ways (Confrey & Smith, 1995). By focusing on change, a covariational approach steers away from the discrete features of function, and furthermore highlights the continuous features of function, in turn, fostering the kind of thinking required for a conceptual understanding of calculus. Namely, the covariational approach exposes the "conceptual underpinnings" of calculus (Johnson, 2012, p. 313).

If students are to be calculus-ready, they need experience with covariational reasoning about function. In particular, types of covariational reasoning align more closely with the concepts of calculus. For instance, researchers have distinguished "chunky" forms of covariation from "smooth" forms of covariation (Castillo-Garsow, 2012; Castillo-Garsow et al., 2013). "Chunky" reasoning involves thinking about change in complete chunks (Castillo-Garsow et al., 2013). In contrast, "smooth" reasoning involves thinking about change as an on-going process. A "chunky" approach is fundamentally discrete because it is built on integers, whereas, a "smooth" approach is fundamentally continuous, because it is built on the real numbers. Research in the area of "smooth" and "chunky" reasoning is emerging. However, researchers agree that "smooth" thinking is critical when exploring the ideas of calculus (Castillo-Garsow, 2012; Castillo-Garsow et al., 2013; Johnson, 2012). Thus, "smooth" covariational reasoning fosters a productive disposition towards calculus.

Promoting "smooth" reasoning through nonnumeric quantitative reasoning

Mentally operating on quantities to construct new quantities, while attending to the relationship between the quantities that were operated upon to construct the new quantity, is quantitative reasoning (Thompson, 1994b). Thus, covariational reasoning is reasoning quantitatively with covarying quantities. Furthermore, Thompson (1994b) argues that at its core quantitative reasoning, fundamental to covariational reasoning, is nonnumeric. That is, quantities are not necessarily numbers; numbers are specific quantities. The process of assigning numerical values to quantities is quantification, but quantification is not a requisite for conceiving a quantity (Thompson, 1994b). Hence, no numeric measurement is necessary to reason with quantities, and quantitative reasoning can be nonnumeric (Johnson, 2012; Thompson, 1994b). I argue that nonnumeric quantitative reasoning can support "smooth" covariational reasoning.

One conceives distance as a varying quantity, when she reasons about a runner's location as a measure of distance, d, from the start of the run. Furthermore, one is reasoning covariationally and quantitatively when she conceives time, t, as a quantity that simultaneously varies with d (Thompson & Carlson, in press). That is, one reasons covariationally about the runner's speed when she conceives rate of change as the ratio of two quantities, d and t. However, if one has a static conception of variable—variable is a symbol for unknown values—then, constructing that ratio does not result in "smooth" covariational reasoning (Thompson & Carlson, in press). In other words, one can conceptualize speed as a ratio without conceiving d and t as continuously changing, but rather, by envisioning constant values for d and t and then comparing those values to conceive the ratio. By doing this one does not attend to the change between the constant values, thereby the reasoning is covariational and "chunky." This aligns with Confrey and Smith's (1995) definition of covariation.

An example of a "chunky" description of speed is "for every eight minutes, distance increases by one mile." This ratio could result in "chunky" reasoning because the relationship is built on positive integers (Castillo-

Garsow, 2012). Without specifying integer value, quantities have no constant value, and then one must relate quantities, thereby attending to change in the quantities, to operate on them, or to reason quantitatively. Thus, I suggest that representing quantities without numeric measurement promotes "smooth" covariational reasoning. For example, reasoning about a runner's distance in relation to the start of her run is reasoning about a quantity with a magnitude, but no numeric measurement. I suggest that nonnumeric quantitative reasoning promotes "smooth" covariational reasoning because it draws attention to the continuity of the variation.

Framework for constructing tasks

In this section, I present a framework for constructing tasks that might support "smooth" covariation. The first three criteria address the context of the task. The last three criteria address the mathematics of the task and will be elaborated on in what follows.

First, the task should involve function. Second, the function should be presented as nonnumeric. Third, when possible, the function should model an experiential situation. For instance, riding in a car is experiential, whereas the growth of a bacteria colony is not experiential. Fourth, tasks should avoid the action view of function (Dubinsky & Harel, 1992). Fifth, tasks should allow for association (Thompson, 1996; Johnson, 2012). Lastly, tasks should involve monotonic functions (Ellis, personal communication, November 3, 2015).

The action view of function involves representing a function as an algebraic expression, whereby students can plug values in for the independent and dependent variables (Dubinsky & Harel, 1992). Such an approach does not prevent students from "smooth" reasoning. However, it is conceptually limiting. Specifically, Dubinsky and Harel (1992) contrast the action view of function with the process view of function and argue that the process view "involves a dynamic transformation of quantities." Essentially, the process view allows students to "think about the transformation as a complete activity beginning with objects of some kind, doing something to these objects, and obtaining new objects as a result of what was done" (p. 85). Hence, the process view of function aligns with quantitative reasoning. Therefore, I suggest that tasks avoid the action view in order to foster quantitative reasoning about function.

Association refers to the mental connections that students construct between objects and attributes of objects (Thompson, 1996). For instance, when considering an area problem, a student is using association by relating side length, perimeter, and area to reason mathematically (Johnson, 2012). Association enables acting on objects, and acting on objects facilitates internalization of the objects and the actions. In turn, association promotes constructing a mathematical mental image. Thompson (1996) claims that images contribute "to the building of understanding and comprehension" (p. 16) and support reasoning about quantitative relationships (p. 15). Therefore, tasks that offer space for association support mathematical image construction, thereby promoting understanding and quantitative reasoning.

A monotonic function is a function that is either always non-increasing or always non-decreasing. Namely, the rate of change does not switch signs. Through personal communication with Amy Ellis (November 3, 2015), I realized the relationship between a function's monotonicity and "smooth" reasoning. Reasoning about a monotonic function supports "smooth" reasoning because there are no points at which the direction of the variation changes.

Conclusions and implications

As the global economy continues to advance technologically, STEM-related careers become more competitive and lucrative. If students are not prepared from an early age to take calculus they are marginalized from the career and economic opportunities afforded by STEM-related careers. At a practical level, I address the lack of calculus preparation in current mathematics curricula. Furthermore, I argue that the current approach is problematic, and potentially detrimental to students' success in calculus. On a theoretical level, I contribute a framework for constructing tasks that promote students' development of a productive disposition towards calculus. Future research could build on this work by scrutinizing and refining the framework. Moreover, a design experiment that iteratively tests the framework in the classroom could inform instruction and curriculum development. However, I recognize that tasks, which fit these criteria, do not guarantee "smooth" covariational reasoning. I also acknowledge that there are many ways to support calculus learning, and that fostering "smooth" covariational reasoning is only *one* approach.

This paper is a thought experiment, and I welcome criticism. I invite readers to share challenging perspectives and tasks that fit the framework criteria.

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Teacher Noticing Associated With Responsive Support of Knowledge Building

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Abstract: Knowledge building is a student-centered, principle-based approach wherein students assume collective responsibility for collaboration and the co-regulation of activity in inquiry within a domain of study with the support of the teacher. Little is understood about the ways in which teachers support knowledge building in the classroom. This paper analyzes to what and how a teacher attends as noteworthy events in the classroom and investigates his associated enacted responses. The construct of teacher noticing was used to identify examples of teacher noticing attuned to students' ideas associated with responsive actions in the classroom in which the teacher supported knowledge building by empowering students to see and make connections to their own and one another's knowledge work and the ongoing trajectory of inquiry.

Keywords: knowledge building, teacher noticing, responsive teaching

Introduction

Knowledge building in the classroom is a principle-based approach in which students' ideas and emerging understandings are the objects of inquiry in a domain of study, commonly with a Knowledge Forum database. Individuals, groups, and the class as a whole define and refine problems of understanding, hypothesize, research, design experiments, share and build on findings, and monitor progress collaboratively with the support of the teacher. The approach is grounded in 12 principles such as community knowledge-collective responsibility, democratizing knowledge, and epistemic agency rather than predetermined curriculum (Scardamalia & Bereiter, 2006). Extant literature primarily focuses on student interactions, idea progression, and achievement often noting that teachers help, encourage, support, and facilitate. But little is known about *how* teachers support students in knowledge building. The construct of teacher noticing provides a framework for analyzing idea-centered responsive teaching. This paper represents first steps in understanding what a teacher attends to and associated enacted responses in a knowledge building classroom.

Knowledge building with Knowledge Forum

The Knowledge Forum (KF) database and companion software, Idea Thread Mapper (ITM), serve as both a record and tool of community progress. Students use customizable scaffolds to (co)author notes recording questions, theories, findings and results of their inquiry in pages in the KF database called views where they can read and build on one another's contributions. They monitor and co-regulate activity based on advances in KF together with face to face interaction, student created artifacts, and knowledge building discourse in the classroom. After initial cycles of inquiry, ITM can be used to display notes related to a specific thread of inquiry along a timeline to help students visualize and assess important knowledge advancement, and to identify potential areas for additional progress (Zhang, Lee, & Chen, 2014). The co-creation of knowledge is driven by students' ideas. The teacher must be aware of and attend to students' evolving thinking in order to make decisions responsive to it, supporting students' productive inquiry (Hammer & van Zee, 2006).

Responsive teaching and teacher noticing

The notion that effective teaching builds on students' own ideas promoting connections between students' understandings and to the domain, and recognizing potentialities is not new. Dewey was a proponent a century ago and episodes from classrooms such as Deborah Ball's are oft cited (Richards & Robertson, 2016). Recently, however, there has emerged a growing research interest in teacher noticing in the field of mathematics education, and in responsive teaching, especially in science education. Researchers from the two fields note concordance and have begun to explore broader questions and purpose (Elby et al., 2014).

Noticing is defined by Jacobs, Lamb, and Philipp (2010) as the interrelated skills of attending to children's strategies, interpreting children's understandings, and deciding how to respond on the basis of children's understandings (p. 172). Noticing expertise embodies the central components of responsive teaching. Importantly, studies with mathematics teachers find that these skills are not necessarily commensurate with teaching experience (Jacobs, Lamb, & Philipp, 2010). Teachers tend to focus on impressions or themselves, take an evaluative stance, and provide little evidence to support their observations (van Es, 2011). Responsive teaching

involves making sense of student thinking rather than evaluating or correcting, attending to the substance of students' ideas and recognizing disciplinary connections (Robertson, Atkins, Levin, & Richards, 2016). This investigation builds on the research on knowledge building by drawing on the foundation established in teacher noticing for identifying teacher attention to students' ideas. In particular, the following research questions explore how a teacher supports knowledge building when his attention is attuned to his students' thinking.

1. To *what* and *how* does a fifth grade teacher attend in a knowledge building inquiry on the human body?
2. What teacher actions in the classroom are associated with noticing attuned to students' ideas?

Methods

One teacher, Mr. C, was selected from three fifth grade teachers implementing knowledge building inquiry for the study of the human body in five science classes in a suburban public elementary school in New York's Capital Region. The data consisted of recordings of monthly teacher meetings and Mr. C's science class periods over the course of the second year of implementation in this setting. Mr. C's classroom recordings afforded the greatest detail in teacher-student interaction enabling the tracking of noted events.

Analyses included two stages. To address the first research question and the first two component skills, teacher meeting transcripts were divided into idea units separated by a shift in topic following van Es's (2011) framework for learning to notice student thinking. Statements made by Mr. C about his class were selected for analysis similar to the focus on individual teachers as is common in studies on noticing (e.g., Jacobs et al., 2010). Mr. C's statements were coded along two dimensions, *what* and *how* he noticed, using the descriptors of the framework (van Es, 2011). *What* encompasses to whom he is referring and the topic, for example behavior, pedagogical strategies, or thinking about the human body. *How* concerns the analytic stance of the remarks (evaluative or interpretive) and depth indicated by detail and evidence in support of his analysis. Segments were considered attuned to students' ideas when Mr. C attended to (what) students' thinking and the relationship to specific aspects of the ongoing trajectory of inquiry, and when his analysis (how) was interpretive and grounded in evidence from events and interactions.

To address the second question, instances in which Mr. C discussed his decision making in response to what he noticed in his class, the third component skill of noticing, were compared to his actions taken in class. In analyzing teachers' deciding how to respond, Jacobs et al. (2010) noted (a) whether the teacher referenced the student's thinking and (b) whether the suggested response left room for the student's future thinking as opposed to only the teacher's. Stated responses, or response options, were analyzed according to these criteria. However, in Mr. C's case, classroom video allowed for the inclusion of actions actually taken. Patterns emerged regarding the types of enacted responses associated with what and how the teacher noticed. Actions associated with noticing attuned to students' ideas are discussed in the next section.

Results

Mr. C attended to a range of issues from student motivation and participation, pace of progress, and pedagogical strategies related to inquiry, to students' ideas and how they connected to students' own and others' work. Statements that were evaluative, based on impressions without supporting evidence, and/or related to the pace of progress tended to be associated with assigned whole class activities or options discussed in the teacher meetings that were not enacted. Though some of these statements referenced student thinking in some way, comments were evaluative and the associated teacher decisions and actions did not leave room for students' future thinking or build on inquiry advances. These findings are similar to those in the literature on noticing.

Reports of math teachers' decision making in the extant literature rely on teachers selecting or creating a fictitious next task. In Mr. C's class recordings there is evidence of how he supports knowledge building. Instances of noticing attuned to students' ideas were associated with teacher decisions and enacted responses in the classroom that helped students make connections to ongoing knowledge building and left space for future advances. The following examples illustrate to what and how Mr. C attended in his statements in the teacher meetings and how he decided to respond, as evidenced by statements and classroom actions, in two such instances (Table 1).

In the first, Mr. C brings students' prior work to the group's attention to help them build on earlier advances and understand their new interest area more deeply through current understandings. He tries to "lead" them from researching disease as a brand new inquiry to thinking about how it connects to their expanding knowledge based on prior work. In the excerpt below he goes beyond suggestion to leading them through steps of connective reasoning. Knowledge building occurs along a trajectory. It is not a collection of isolated inquiries within a domain. Mr. C notices enthusiastic interest developing in a group but interprets the students' interactions as a possible disconnect from the ongoing knowledge building.

The second example shows how the teacher pulls students together from diverse areas of inquiry to help them see that their research and new questions are converging into a promising direction that is new to the class. He suggests a similarity in that their new interests are related to what is going on in the body while it sleeps while emphasizing the diversity of their questions. He allows students to share thoughts and experiences but then brings them back, twice, to the connections between their interests. He suggests that this could be an area of research that is new to the class, but leaves it to the students to decide if it fits within an existing topic or needs its own. He asks them to consider how they will word a question that encompasses the diversity of their interests and picks up with the formulation of that question in the next class. Mr. C notices the inquiry of several students in diverse groups heading in the direction of sleep which is not a big topic area for the whole class. He interprets this as an opportunity for new collaborations and advancements in understanding. He encourages collective responsibility for wording a single question that can encompass their diverse interests.

Table 1: Actions associated with noticing attuned to students' ideas

Statement from teacher meeting	Action taken in the classroom
Mr. C: If you've done this work, the knowledge that you have about white blood cells. Look into that and then diseases may pop up instead of the opposite way around. Try to lead them in that direction.	Mr. C: A good way to get into the field that you find exciting is to use your information about blood that you know, circulatory system, things like that, to get to diseases. Because there is definitely a connection, literally and figuratively. S1: Oh, I know what you mean. You're talking about since we're blood, we won't have to start a new group. We can start moving toward the disease. Mr. C: Right. That's exactly right. But it's not even so much that. You can probably end having a new one, a new section. But it's that fact that you're kind of building off of the information that you already know. Instead of starting from scratch. S2: I don't think we should go off from what we already have. Mr. C: Well, how do I say this? This is what you've got to remember. Another name for circulatory system is the cardiovascular system. It delivers. What does the circulatory system deliver to the. . S3: Blood. Mr. C: Blood. What's in blood besides. . S1: Cells S3: Blood cells, white blood cells, oxygen, nutrients S2: Germs Mr. C: Germs. And the white blood cells fight them. That was one of our things. S3: Sometimes there may be too many germs. Mr. C So fatal diseases are infecting your blood. . . It sounds like you guys are interested in fatal diseases but you should use what you already know.
Mr. C: The sleep people, they had different parts. One was interested in REM sleep. And one was interested in like sleepwalking. Another one was sleep disorders. They all kind of have like different areas. Dreams, that's another one. That they're interested in. We figured that there's enough subtopics of it for it to be its own thing.	Mr. C: Could I throw this out to you? Now if you think about how does the brain do its job. So you're sleeping. Your whole body is, sleeping. Right? It's resting. Whatever it is. Your heat's still beating. You're still breathing. You still have those things, those parts of your body that you're not consciously thinking about, breathing, heart beating, digestion, things like that. So, all of a sudden, now you add into it, um, there's other things happening as well, right? Like you guys were talking about dreaming. Talking about if you were sleepwalking, like you're unconsciously using your motor skills. (student stories) Mr. C: I guess what I hear is you guys have a lot of questions about unconscious times when you're kind of, really sleep. What's happening during sleep. (student stories) Mr. C: This is like, what I'm hearing you guys say is a ton of different questions or observations that you have, that you've either experienced, heard about, you're wondering about. And, it seems like a very large area of research. It seems like a large place that you could all, so would you like to make it its own question? Or do you think it's part of brain and part of its jobs? S1: Its own question. (Others agree) [End of class. Mr. C asks group to think of wording for a big question.] (Next class) Mr. C: People who had some interest in having dreams being something about, or sleeping, or dreams, and it's something a lot of people were talking about so let's come up with a big, juicy question for it. And then people can go about what they're going to do. . . What do you guys think that could be a way of phrasing this big juicy question that could *include* kind of what everybody's interested in. What were people interested in?

Conclusion

The implementation of knowledge building depends on responsiveness from the teacher as students' ideas are the objects of inquiry. Mr. C's above responses demonstrate instances of noticing attuned to students' thinking highlighting connections between students' ideas, to the domain of study, and to the trajectory of understanding advancement in support of knowledge building.

This paper represents an exploration of teacher noticing as a framework for beginning to understand the ways in which teachers can support students in knowledge building. There is no best response in teaching situations. There is always a range of reasonable responses (Hammer & van Zee, 2006). The construct of teacher noticing provides a way to identify when teachers' attention is attuned to students' ideas and a means to classify decisions as being responsive to the teacher's interpretations of that thinking. The examples demonstrate that a focus on the teacher's noticing may lead to a greater understanding of ways in which teachers can support students in knowledge building; they are not meant as exemplars. The above examples are but two from all that a single teacher chose to discuss in teacher meetings. They are not necessarily representative of his in-the-moment decision making in the classroom. The next phase of this work involves having teachers keep semi-structured reflection journals modeled on the dimensions of noticing throughout the current, full-year fifth grade inquiry on the human body.

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The Study of Cognitive Development in the Structured Collaborative Learning Task Mediated by Semantic Diagram Tools

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Abstract: This paper presents the findings from a recent study of two collaborative concept-mapping task mediated by semantic diagram tools with grade 7 students (n=25) in an urban high school in Canada. Data was collected from the pre-post paper-based test to evaluate student's understanding of the learning topic and from the Mural map to evaluate student's CPS engagement and interaction in different learning task. The result was that the cognitive development is improved in the structured CPS learning tasks under the mediation of semantic diagram tools. While, the basic understanding, rather than the high level understanding of learning topic is improved. What's more, the CPS interaction, rather than the CPS engagement make the positive contribution to the cognitive development. This finding gives some insight of design of the CPS learning task and semantic diagram tools in the future study.

Keywords: learning task, CSCL, visualization tool, cognitive development, engagement, interaction

Introduction

How to support student's cognitive development in the computer-supported collaborative learning environment is an important research issue. Based on the social-cultural perspective of learning, many pedagogical and technological supports have emerged from CSCL research (Kobbe et al., 2007). The consensus in the field is that collaborative problems solving (CPS) process and outcomes can be improved greatly when they are appropriately structured (Ertl, Fischer & Mandl, 2006). What's more, visualization tools support collaborative problem solving, allowing learners to construct representations jointly, by providing external mental processes in the form of concept maps, diagrams and, and text (Lu, Lajoie & Wiseman, 2010). Therefore, in this study semantic diagram tools are argument with those kinds of visualization tools to support CPS process to maximize the benefit of collaboration for individual cognitive development. The goal of the study is to preliminarily investigate the effect of cognitive development in the structured collaborative learning task mediated by semantic diagram tools. The research questions are: (1) What's the result of cognitive development in the CPS mediated by semantic diagram tools; (2)What's the difference of learner's CPS engagement and interaction in the different collaborative learning task with the mediation of semantic diagram tools; (3)What's the impact of learner's CPS engagement and interaction on the student's cognitive development?

In order to answer those research questions, a designed-based method was employed to create a 4-day CPS learning project with a 7th grade classroom teacher. In the CPS learning project, students worked in various small group configurations to understand topics of food and nutrition, culminating in an activity where they created a healthy food plan. The web-based software Mural acted as semantic diagram tools in this study. It has the basic technological function for concept mapping. For example, it allow student to add visual objects such as shapes, sticky notes, arrows, or picture that reflect their understanding of the specific learning topics. But also, it has some extra technological function for social interaction. For example, it allows multiple users to be online, editing the same concept map simultaneously – seeing one another's edits, and communicating through a chat window, make some comments to any visual objects. After examine the pre-post test data and the learning process data in the Mural in the CPS project, some findings were revealed for each question. These first-round findings will inform our next design iteration, to focus more on support the high level understanding of the learning topic meditated by semantic diagram tools.

Methods

Participants and study context

This study involved 25 female students in an urban high school in Canada. The participants were 7th grade taking regular high school health science classes. The teacher was a veteran of more than 10 years' experience working at this school, and an important member of the curriculum design team. A design-based research method was employed to design a learning project on Food and Nutrition in the WISE platform which orchestrating the

delivery of materials (including many suitable visualization tools) and collects all student learning process and result data for purposes of analysis.

Procedure

The CPS project took over four 70-minute class periods in this study. In the first class period, the teacher administered a 30-minutes pre-test and then make some introduction of the learning topic, the learning environment WISE, the semantic diagram tools Mural. In the second class period, teacher made some orientation learning activity, and then student logged in the Mural and finished the learning task 1 about *drawing the nutrient map*. The learning goal was to help student understand the function of each nutritional category. The 25 students were assigned into 6 groups, with each group responsible to make a collaborative concept map of one of the nutritional categories, based on their readings of relevant learning materials. We designed a "starter map" that included some of the basic nutritional elements (see Figure 1), and some starter links, such as "role within the body", and "supplied by what sources". This served to scaffold students in creating maps with relevant conceptual connections, focusing on the salient aspects of their food category.
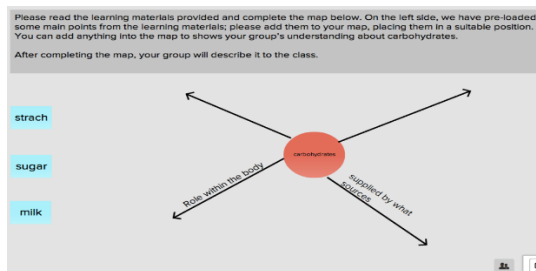
Figure 1. The starter map in the learning task 1.
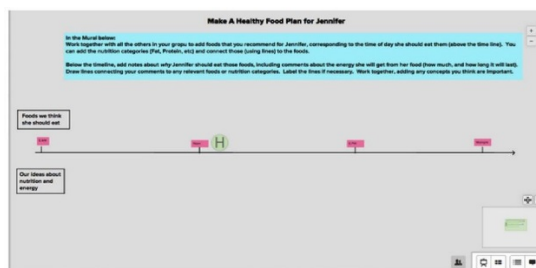
Figure 2. The starter map in the learning task 2.

In the third class period, firstly the teacher made some orientation learning activity. Then students logged in the Mural and finished the learning task 2. Compared with the learning task 1, the second one was more open-ended, which was about *How to make a healthy food plan*. They should think of a healthy food plan for a fictional student named Jennifer, who had been introduced earlier in the first class period. In this activity, new Mural groups were created with 6 students using a jigsaw pattern, where new groups of six students were assembled from member each of the previous groups. They were required to make a Mural map for "How to make a healthy food plan for Jennifer". Once again, a "starter map" was created (see Figure 2), this time in the form of a time line, from 6 AM to midnight, with a clear prompt in the area above the time line, "Foods we think Jennifer should eat" and below "our ideas about nutrition and energy". Students were asked to draw as many lines of connection between different foods, and ideas, as possible. In the four class period, the students were allowed to review their learning artifacts on the Mural map, and then made their conclusions of the CPS learning project. The post-test was finished in this period.

Data collection and analysis

Data from pre-tests and post-tests

In this study, student's cognitive development is measured in the identical paper-based tests before and after the CPS learning project. The 30-mins test included eight true-or-false items and three fill-in items that aimed to evaluate students' basic levels understanding of learning topics. The two open-ended items were used to evaluate students' high level understanding of the learning topic. For the eight true-or-false items and three fill-in items, "1" or "0" were recorded for the "correct" or "incorrect" answer. For the two open-ended items, a knowledge integration rubric (Linn, Lee, Tinker, Husic, & Chiu, 2006; Liu, Lee, Hofstetter, & Linn, 2008) was employed to code students' depth of understanding. The knowledge integration scores ranged from 0 to 4 and higher scores indicate more right and reasonable understanding about food and nutrition. Therefore students earned highest scores by showing their understanding of the relationship between food and nutrition.

Data from Mural

In this study, student's CPS engagement and interaction are evaluated from the Mural tracing data. Specifically, six episodes of group's learning tracing were collected from six Mural maps in the task 1. Four episodes of group's learning tracing were collected from four Mural maps in the task 2. The recoding form from Mural map recode the student's manipulation on the interface is [user's name A], [performance], [the visual object], [time]; [user's name B], [performance], [the visual object], [time]. Specifically, the "performance" includes deleted, added and

so on. The visual object includes text, image and arrow. Take the Figure 3 for example, Candice Chow add an image 11:18AM. And then Emily Zhang deleted a sticker at 11:18AM. While, Beral added a sticker at 11:18AM.

Each episode of Mural tracing data was firstly transferred into Excel in terms of the four fields, such as *what time, who, the manipulation times of the visual objects, what kind of the visual objects*(such as text, image and arrow). One episode of Mural tracing data is visualized according to the four fields, as shown in Figure 4. Based on that, the student's status of engagement and interaction can be analyzed. For student's CPS engagement in each task, it can be measured by the ratio of the certain student's manipulation times in the Mural interface to the whole group's total manipulation times in the Mural interface. For example, in the learning task 1, Jen manipulated 18 times on the Mural map, while her group managed 94 manipulation times. Therefore, Jen's engagement in learning task 1 is 18/94, namely 0.194. In the learning task 2, Jen manipulated 35 times on the Mural map, while Jen's group managed 243 times manipulation. Therefore, Jen's engagement in learning task 2 is 35/243, namely 0.144.For student's interaction in each task, it can be measured by the degree of centrality in the group, which is a simple tally of the number of people attached to each person. It can be calculate by the method of social network analysis by the social network analysis software, UCINET.

Figure 3. The example of Mura tracing data.
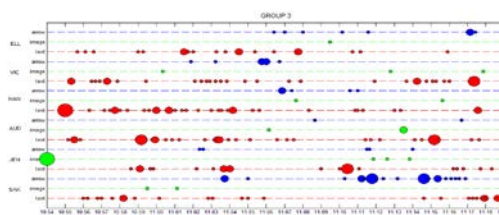
Figure 4. The visual Mural tracing data in the time sequence.

Findings

Analysis of cognitive development

Table 1: Result of Student's Cognitive development

	Pre-test (N=19)		Post-test (N=19)	
	Mean	SD	Mean	SD
Basic understanding	0.57	0.17	0.79	0.13
High level understanding	0.50	0.15	0.46	0.17
Total understanding	1.07	0.27	1.25	0.23

Table 2: Result of Student's engagement and interaction

	Task1 (N=19)		Task2 (N=19)	
	Mean	SD	Mean	SD
CPS engagement	0.27	0.14	0.17	0.06
CPS interaction	0.25	0.11	0.18	0.05

A paired-sample t-test was employed to compare the students' pre-test and post-test scores to evaluate student's cognitive development during the CPS learning project. Means scores and standard deviations of learning gain and concept map items in the pre-test and post-test are present in Table 1. As shown in Table 1, there is significant different between pre-test and post-test scores in term of total understanding of the learning topic (t=-3.86, P=0.001<0.05). It means that student's cognitive development of the learning topic were improved after the CPS learning project. Besides, there is significant different between pre-test and post-test scores in terms of basic understanding of the learning topic (t=-6.89, P=0.000<0.05). This indicates that as a result of the intervention, students' conceptual understandings of food and nutrition have made some change for the better (e.g., of topics such as which foods are not nutritional, and which foods are in certain categories). However, no significant different exists between pre-test and post-test in terms of high level understanding (t=0.90, P=0.379>0.05), indicating that students' understanding of the relationships between food and nutrition did not improve. As a result of this project, students may not have formed deep understanding about the functions of different nutritional categories and the relationship among food, nutrition and body.

Analysis of CPS engagement and interaction in different tasks
A paired-sample t-test was employed to evaluate the student' CPS engagement and interaction in the two different tasks. Means scores and standard deviations of CPS engagement and interaction in task 1 and task 2 are present

in Table 2. As shown in Table 2, there is significant different between task1 and task 2 in term of CPS engagement (t=2.92, P=0.009<0.05) and CPS interaction (t=2.92, P=0.009<0.05). The students have engaged more in the task 1(M=0.27, SD=0.14) than they have in the task 2(M=0.17, SD=0.06). The students had more intensive interaction with each other in the task 1(M=0.25, SD=0.11) than they have in the task 2(M=0.18, SD=0.05). The task 1 is designed based on the basic knowledge of food and nutrition, while the task 2 is designed based on the intention of allowing students apply what they have learned to solving a real problem. In terms of complexity, task 2 is more complexity than task 1. Whether the complexity of learning task affect student's CPS engagement and interaction needs further investigate.

Analysis of the relationship between cognitive development and CPS engagement and interaction in different tasks

The path analysis by Amos software is employed to evaluate the relationship among cognitive development, CPS engagement and interactions in different tasks. Figure 5 portrays the result of this analysis. From the positive path coefficient of CPS interaction with cognitive development of the learning topic, it can be inferred that CPS interaction mediated by semantic diagram tools in the task 1 and task 2 make positive contribution to the student's cognitive development. It means that collaborative concept mapping individual's knowledge and understanding in the semantic diagram tools is a promising way for student's cognitive development. In the shared learning space, students can create the learning artifacts that present their knowledge and understanding of the learning topic, they can view the learning artifacts from their peers, which may stimulate them to think, or allow them to help the creators to make the learning artifacts better. On the other hand, for the negative path coefficient of the CPS engagement in the task 1 and task 2 with the cognitive development of the learning topic, it can be inferred that students may unconsciously manipulate the visual elements on the Mural map, which do not stimulate student's deep thinking or reflection. It uncovers our researchers that there should be some apparent and directed hints for students' manipulation of the visual elements to stimulate student's deep thinking.
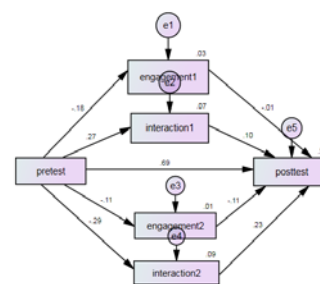
Figure 5. The result of path model.

Conclusions and implications

This paper reports the first stage of our study, which is to investigate the effect of cognitive development in the structured collaborative learning task mediated by the semantic diagram tools. An important outcome of the study is that integrating semantic diagram tool into the CPS learning task is a promising way to support student's cognitive development. In terms of analysis of the learning process, it could be found that, semantic diagram tool integrated the CPS learning task open a new window to investigate student's process status in the collaboration. The CPS interaction and CPS engagement mediated by semantic diagram tools in different task and their relationships with the cognitive development is explored in this study. How to take the advantage of semantic diagram tools to support the CPS interaction and engagement in structured CPS task in order to improve the deep learning should be the focus in the further study. What's more, those preliminary finding in this iteration could give some insight of future research, such as how to design suitable complexity learning task in CPS to support student's cognitive development; how to make student engage into the CPS learning task; how to support the deep thinking in the CPS mediated by semantic diagram tools and so on.

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Uncovering Teachers' Pedagogical Reasoning in Science Discussions

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Abstract: We report on research in progress that examines how teachers reason about and make pedagogical decisions in the context of science discussions. We developed and administered a high-fidelity multimedia survey instrument populated with segments of class discussions and open-ended questions to expose 1) teachers' reasoning about student thinking in science discussions and 2) what pedagogical moves they would make in light of their reasoning to advance the discussion. The findings show distinct qualitative differences in the way novice and more experienced teachers *see* dialogic and conceptual processes in science discussions. They help to identify places where teachers may need support in developing their pedagogical reasoning in science discussion.

Keywords: pedagogical reasoning, science education, classroom discourse

Introduction

Growing evidence shows that when teachers lead students in argumentation (i.e., collaborative problem-solving discussions that externalize student thinking and reasoning), students benefit with steep increases in learning (c.f., Resnick et al., 2015). However, it is rare to find teachers using discursive pedagogy in K-12 science education, despite growing value placed on the role of argumentation for science learning from both research and government initiatives such as the Next Generation Science Standards (McNeill & Pimentel, 2010; NGSS, 2013). Several teacher development interventions on dialogic pedagogy in science have shown that it can take several years before it is possible to see significant changes in the ways teachers use talk to foster conceptual learning in science (Clarke et al., 2013; Osborne et al., 2013). This raises a critical question: why is it challenging for teachers to appropriate dialogic pedagogy to support students' science learning?

In this paper we report on the first phase of a design study to examine teachers' pedagogical reasoning in whole-class science discussions, with the goal of developing targeted support to bridge the gap between teachers' cognition and classroom practice.

Theoretical framework

Recognizing the critical role that teachers play in orchestrating science discussions and the difficulty in doing so, there has been growing interest in teacher professional development as a means by which to make argumentation in science widespread practice (Osborne, 2015). Several studies have focused teacher training on how to elicit specific features of argumentation (e.g., claims, warrants, probing for evidence) to make student reasoning public in order to develop students' conceptual understanding and skills in argumentation (Clarke et al., 2013; Osborne et al., 2013). These studies show that teachers can gain a theoretical understanding of scientific argumentation and 'talk moves' through training, but the uptake of these moves in classroom instruction has been modest. Several studies have found that science teachers have difficulty analyzing written and oral representations of student reasoning and knowing how to respond to them in productive ways, even within the context of professional development (McNeill & Knight, 2013; Levine et al., 2009). In subsequent work, McNeill and colleagues rigorously developed and tested an instrument to assess teachers' pedagogical content knowledge (PCK) of science argumentation (teachers' knowledge of student thinking in science and knowledge of instructional strategies in science argumentation). After piloting and refining their instrument with 103 middle school science teachers, they concluded that teachers' PCK of science argumentation consists of two core abilities - the ability to evaluate and support students in justifying their claims, and the ability to evaluate and support students' transactive reasoning in argumentation (McNeill et al., 2015).

Building on this work, we argue that in order to develop approaches that narrow the gap between a) teachers' theoretical knowledge about facilitating science argumentation and b) their practical action in the classroom, there is a need to understand *how* teachers reason about what happens in science discussions, and precisely *how* their decision making in facilitating discussions is tethered to that reasoning.

In this paper we report on the first phase of a design study on pedagogical reasoning and action in whole-class science discussions in complex social settings. By pedagogical reasoning, we refer to the sense-making processes that teachers are constantly engaged in while facilitating argumentation in class, such as reasoning about student ideas, enacting instructional goals, calling to task their pedagogical repertoire to make instructional decisions in light of their sense-making, and finally, taking action. Following Shulman, (1987), we conceptualize pedagogical reasoning as a facet of the larger construct of teacher cognition, PCK. In this study we focus on understanding the nature of pedagogical reasoning in science discussions to inform the development of an educational technology designed to support teachers in learning how to productively facilitate science argumentation.

The goal of this study was to examine teachers' pedagogical reasoning and decision making (hereafter referred to as *action*) in biology classroom discussions. The questions guiding this study were: *1) what is the nature of teachers' pedagogical reasoning about science discussions?* and, *2) what is the relationship between teachers' reasoning about discussions and (intended) actions*? Building on McNeill and colleagues (2015), we developed, piloted, refined, and administered an instrument designed to elicit teachers' tacit reasoning in class discussions by focusing specifically on moments in biology discussion that require a pedagogical action on the part of the teacher. However, in contrast to previous work, a core design principle for our instrument was to preserve the rich, often messy complexity of real classroom interaction data in our instrument. Since teachers have competing demands on their attention during teaching (Levine et al., 2009), our interest was in understanding the nature of teachers' reasoning when the complexity of those interactions were preserved.

Methods

Our instrument consists of hi-fidelity multimedia scenarios constructed from whole-class discussions previously collected as part of a large-scale longitudinal study on Accountable Talk® biology discussions (Clarke et al., 2013; 2015). Since teaching science through scientific argumentation means situating opportunities for argumentation within particular scientific problems (Brown et al., 1989), our scenarios were constructed with segments of discussion bounded within a single lesson in the BSCS biology curriculum – Punnett Squares. To select discussion segments, we reduced the dataset to lessons on Punnett Squares, then used theoretical sampling to reduce the dataset further to segments where students disagreed on the content. We predicted that these sections of lessons would be a hotbed for academically productive talk, as previous research has shown that disagreement yields other productive dialogic interaction (e.g., explanations, elaboration and transactive reasoning) (Howe, 2010). We selected seven such moments as they presented opportunities for teachers' pedagogical reasoning and action, such as: sequences of disagreement between students, expressions of misconceptions, and moments where challenges were issued by the instructor or fellow students.

We developed seven video scenarios to embed in the instrument using the audio recordings from the original dataset and enhanced them with a scenario framing that situates the activities within the flow of the discussions, real-time transcription of the audio during playback (for speaker management), and board representations of the Punnett Squares being discussed (for deictic management). We then developed a set of open-ended questions for each scenario to expose 1) teachers' reasoning about the scenario in terms of students' thinking and its emergence in discussion, 2) evidence teachers could identify to support their interpretation of student thinking, and 3) what they would do next to advance the discussion; e.g., "What do you think is Aamir's current level of understanding? What is your evidence?". To further situate teachers reasoning about these scenarios, we imposed a set of instructional goals that fit the lesson for teachers to operate on in their explanations of their reasoning about student thinking and what actions they would take in light of that reasoning. Goal 1 was for students to reason probabilistically about genetic inheritance using Punnett Squares as a tool to calculate probability, and Goal 2 was for students to provide evidence of their reasoning. In this we sought to better understand how teachers were making sense of action in science discussions in terms of proximal and distal goals (proximal = managing moment-to-moment dialogic processes; distal = leveraging dialogic processes towards achieving a conceptual end). All speakers had pseudonyms and we elided any names present in the audio. Audio was not otherwise modified.

We then conducted two design and evaluation cycles of the instrument, and we report on the findings from iteration 2 in the rest of this paper. Teachers were recruited via an email flyer distributed through teacher leaders in two urban high schools that serve diverse populations of students in the United States, and received $40. Six science teachers responded to the survey (two first year teachers (novices), two 3rd year teachers (mid-level), and two teachers with greater than five years (experienced). We instrumented several qualitative analyses in order to address our research questions. First, we developed a 5-point scoring rubric to score responses in terms of the extent to which responses diagnosed an opportunity for pedagogical action, and the rationale for the action they proposed (e.g., identifies a misconception vs. identifies which student has a misconception and what that

misconception is). Responses were scored by two raters, with a "very good" interrater reliability score (kappa=.88) calculated on the first two segments. Any disagreements were then discussed. We then used these codes to explore the data with respect to teachers' level of expertise to examine qualitatively how their reasoning was elaborated on. We report findings below.

Findings

Our analyses produced several key findings. First, with respect to diagnosing decision-points in discussion, experienced teachers were able to successfully diagnose points where a pedagogical decision was required despite the purposely preserved "noise" of the scenarios, scoring a median of 3 (on a scale of 0-4) across scenarios and never below a 2. In addition, although our scenario questions were purposefully open-ended, both experienced teachers identified the same decision-points that our research team had identified when selecting the segments as likely candidates for pedagogical reasoning scenarios. Moreover, one segment was included in the set because it contained only evidence that students were accurately applying and reasoning about the solution. We reasoned this would provide a crucible for examining how teachers reason about conceptual accuracy in discussion in the process of building a larger explanation of genetic inheritance (i.e., do teachers make connections to previous concepts, move on to new concepts, etc.). Experienced teachers' responses to this scenario showed that they were able to correctly identify the conceptual accuracy of students' responses. Overall, experienced teachers explicated both their reasoning about the dialogic processes of discussion (e.g., disagreements, challenges, clarifications) and the conceptual processes of the discussion (e.g., the relationship between the proposed genotype and the expressed phenotype).

> *Students are presenting their thinking about the genotypes of the cats and attempting to support their thinking with explanation of how their genotypes fit the parent cats...Phil was able to see past Aamir's solution to how it could be possible for the orange parent cat could be heterozygous. At no time however did any students express their thinking in probabilities or by referencing evidence beyond the explanation of what they could see.* (T1: Experienced)

We found that novices, however, did not explicate their reasoning about segments beyond the general description that students were participating in discussion. These teachers scored a median/mode of 1 (described interaction in general terms), as in T5: "*In this segment there is a small group discussion on inheritance.*"

Mid-level teachers also scored a median of 3, but scores ranged from 1-4. At times they described the interaction rotely, as in T4: "*The teacher gives a prompt. Then one student responds with his answer and explanation. The next student gives his answer and explanation. The teacher then cues the other group members to speak. They agree.*" In the same scenario, T3 identified a specific pedagogical issue: "*The two responding students have obviously different levels of understand[ing], and the class doesn't see the difference.*" In other scenarios, T4 was equally able to articulate such a response. Their expertise at recognizing pedagogical issues appears to be emergent, which may explain their ability to explicate reasoning more substantively at some times but not others.

With respect to pedagogical actions in light of their reasoning, experienced teachers frequently took into account the current state of the class discussion and tied their next steps directly to the problem that they believed was happening, e.g., T2: "*I feel like the students are missing the recessive phenotype and I would want to pull the class back to examining the phenotypes of the adults again.*" Novices, however, generally indicated that they would either continue the current trajectory (e.g., T6: "*I would continue the activity by have the students draw out the Punnett square and discuss what they found*"), or they suggested that they would switch to something else entirely (e.g., T5: "*I would just make sure that the problems are on the board to give them a visual reason to believe it as well.*"). In addition, for every single scenario, novice responses indicated that they believed the distal goals were being met, and their proposed follow-up actions made no connection to these goals. Distal goals were introduced at the beginning of the survey, and again in each scenario accompanying question probes about whether the goals had been met within the segment. Instead, their responses focused on proximal aspects of the interaction and only in very general terms.

Third, with respect to the content, novices provided evidence of lack of understanding of the science content being discussed within scenarios (e.g., excerpts below).

> *Phil was probably at a slightly lower level of understanding because he believed that the color of the litter was by chance or luck which is a possibility but when there is only heterozygous allele there is no way for there to be any other color other than dark orange.* (T6: Novice)

> *Phil probably has an advanced level of understanding since he was able to see that there was more than one answer and [the] probabilities.* (T2: Experienced)

We interpret these differences by experience level as fundamental differences in how teachers *see* the interactions in science discussions.

Conclusions and implications

While the sample size is small, the dataset from this instrument is rich, and the findings indicate there are distinct qualitative differences in the way novice and more experienced teachers *see* dialogic and conceptual processes in science discussions. Mid-level and experienced teachers show greater specificity in their diagnoses of scenarios and rationales for intended actions in light of problems they identify. In addition, mid-level and experienced teachers demonstrated an adeptness to weed through the 'noise' of classroom discussions and attend to student thinking. Novice teachers were not able to identify moments where there were conceptual impasses in discussion that merit the intervention of the teacher, and the strategies that they propose for moving discussions forward are general rather than content driven. However, we caution the conclusion that novices lack pedagogical reasoning or PCK. We think these findings provide evidence that novice teachers' reasoning attends primarily to surface features of classroom interaction. Thus, these findings raise the question of the extent to which novices' decision making is tethered to substantive features of class discussions.

These findings help to identify places where teachers may need support in developing their pedagogical reasoning in science discussions. In addition, they show that dexterity with dialogic processes may not be the only, or most pressing challenge for teachers' use of dialogic pedagogy. Rather, issues may lie in teachers' understanding of the content, and thus interfere with their ability to assess students' evidence and claims (proximal goals) and then efficiently use these processes towards achieving a conceptual end (distal goals).

This study contributes to growing scholarship in the learning sciences on teacher learning processes. We provide insight into teachers' reasoning processes engaged in the midst of dialogic discussions in science, and thus some of the challenges of facilitating dynamic discourse processes. In future work, we seek to leverage insights from this instrument to develop an adaptive educational technology to support teachers' learning.

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Acknowledgments

Investigating Analogical Problem Posing as
the Generative Task in the *Productive Failure* Design

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Abstract: Research on *Productive Failure* and preparatory mechanisms has consistently demonstrated a positive learning effect when students generate problem solutions before receiving formal instruction. However, it has been less examined whether the effect still holds when the generative task does not involve problem solving. Using a 2x2 experimental design, this study investigated the effects of generative tasks that involve analogical problem posing (without solving) on learning and transfer. Pedagogical sequence (i.e., generation-first or instruction-first) and type of analogical reasoning task (i.e., generating one's own analogical problems or generating analogical mappings between given analogical problems) were the two factors manipulated. Preliminary analysis revealed no multivariate effects of the factors. Thus, we discuss the learning mechanisms enacted by analogical reasoning, reliability of the instruments, and the participants' prior condition as possible reasons and to inform future studies.

Introduction

While teachers often provide students direct instruction before having them generate their own ideas, problem solutions, or conceptions of topics, recent studies on *Productive Failure* (Kapur, 2008, 2010) have shown the benefits of allowing students to generate first, at the onset of learning, and afterward receive direct instruction (Kapur, 2014; Loibl & Rummel, 2014). These studies show that students who generate (G) first and receive instruction (I) later (which we refer to as the G-I sequence) experience an initial performance dip after the generation phase, yet have subsequent success in learning after instruction. This is the crux of the *Productive Failure* phenomenon. Schwartz and Martin (2004) explain that a generative type of task prepares students for their future learning in a subsequent phase of direct instruction, such as a lecture.

The existing *Productive Failure* work uses problem solving as the generative task, and Kapur (2012) has found that the number of (typically suboptimal) solutions that students generate is positively correlated to learning outcomes. However, there are other types of generative tasks and it is an open question as to whether the Productive Failure phenomenon would still apply. For example, prior work has shown that the generative activities of summarizing a text (Grabowski, 2004) and self-explaining (Chi, De Leeuw, Chiu, & LaVancher, 1994) produce better outcomes than less generative activities (highlighting and reading the text twice, respectively). However, these works did not involve a manipulation of pedagogical sequence.

An extended question is whether activities that offer more degrees of freedom in generation may lead to better learning and transfer. By this, we mean tasks that have multiple possible canonical answers. It makes sense that in general, learning activities that cognitively engage students in similar ways (e.g., generating ideas, rules, principles, solutions, etc.) would produce similar learning outcomes (Chi, 2009). However, studies by Loibl and Rummel (2014) and Kapur (2014) both suggest that different types of generative tasks may lead to different learning effects. For example, in Kapur's (2015) work on problem posing, which has more degrees of freedom as students may pose problems with different problem goal states, results showed that posing problems led to better transfer outcomes than solving problems, but worse conceptual knowledge outcomes. Thus, differing degrees of freedom may lead to learning and transfer trade-offs, and testing these effects is necessary.

In this study, we examine analogical problem posing (Gentner & Holyoak, 1997) as the generative task, because analogical reasoning—the underlying cognitive process—has a substantial possibility for varying the degrees of freedom. In analogical reasoning, leaners perceive relational similarities (Gick & Holyoak, 1980) between two problems, recognize them as an analogy, and transfer prior knowledge (i.e., problem solution) from one problem (i.e., source) to the other (i.e., target). Holyoak and Koh (1987) regard relational similarities as problem structures that are functionally relevant to solving the source and target problems. Analogical reasoning is found to help students focus on relational similarities rather than on idiosyncratic surface features between two situations (Gentner & Markman, 1997). For example, Gentner, Loewenstein and Thompson's (2003) study on the transfer of negotiation strategies shows that explicitly comparing source and target cases that share a common underlying principle can be illuminating even if the common principle is only partially understood in either case.

We used analogical reasoning in two different ways to correspond to different degrees of freedom in generation. One type of activity is called Student-Generated Analogous Problems (SGAP). SGAP requires students to generate their own analogical problems to a given problem, compare and contrast the similarities and differences, and make modifications of their analogies. The other type of activity is called Teacher Given Analogous Problems (TGAP). TGAP requires students to generate and encode relational similarities between the source and target problems (which are both given by the teacher). This process is called analogical mapping (Gentner & Markman, 1997) or analogical encoding (Gentner et al., 2003). The SGAP and TGAP tasks differ in degrees of freedom in generation; in the SGAP task, one problem may have many possible analogues whereas in the TGAP task, the similarities between two given problems are limited and fixed. Thus, to extend the understanding of the *Productive Failure* phenomenon, in this study we used SGAP and TGAP tasks to differentiate generativity of the tasks.

The main research questions addressed (a) whether the effect of pedagogical sequence holds in analogical problem posing and (b) whether the degrees of freedom in generation in analogical reasoning tasks affect the outcomes of pedagogical sequence.

Methods

A 2x2 experimental study was conducted using the factors of (a) pedagogical sequence (Generation first-Instruction later, G-I, vs Instruction first-Generate later, I-G) and (b) generative task (student-generated analogous problems, SGAP, vs teacher-given analogous problems, TGAP). Thus, there were four conditional groups in this study: SGAP-I (i.e., students generating analogous problems, followed by instruction), TGAP-I (i.e., students generating analogical mappings for teacher given analogous problems, followed by instruction), I-SGAP, and I-TGAP.

Sample

The study was conducted in an all-girls high-achieving secondary school in Singapore. A total of 117 seventh-grade girls from five classes took part in the study at the end of the school year. Participants were randomly assigned to conditions, which took place in two different instructional environments (1). Six students had missing data, representing 5.13% of the total participants. Therefore, our total sample size was 111: 25 in SGAP-I, 29 in TGAP-I, 26 in I-SGAP and 31 in I-TGAP.

Materials and measurements

The learning goal was to formulate a system of linear equations for word problems. Three measurements were collected on student prior ability. As formulating equations for word problems requires math knowledge and language comprehension ability, the participants' national exam results from sixth grade (referred to as PSLE) were collected as a measurement of their general academic ability (2). We collected the participants' analogical reasoning ability (i.e., AR ability) using domain-free pictorial items isomorphic to Raven's Advanced Progressive Matrices (Raven, Raven, & Court, 1998). The instrument measured the participants' domain-free general ability. The Cronbach's α of the 16-item AR test was .65. The participants' prior knowledge specific to algebra (i.e., prior algebraic knowledge) was measured by a 10-item pretest concerning the conceptual knowledge of algebra and the ability to formulate linear equations for one-variable and two-variable word problems. Of the ten items, one was excluded from data analysis due to its low reliability. The Cronbach's α of the final 9-item instrument was .64.

The posttest comprised three measures. A six-item learning instrument measured the participants' ability to formulate a system of linear equations for word problems with two and three unknown variables. One item was excluded from data analysis due to its low reliability. The Cronbach's α of the final five-item instrument was .55. A posttest with four items on conceptual knowledge measured the participants' understanding of algebraic representations involving three variables. One item was excluded from data analysis due to its low reliability. The Cronbach's α of the final three-item instrument was .75. A six-item posttest on transfer measured the participants' ability to formulate equations for word problems involving four unknown variables, nonlinearity, and inequalities. The Cronbach's α of this instrument was .60.

Procedures

The study involved four sessions and each session lasted about one hour. All participants took the AR and algebra pretests in Session 1 and posttest in Session 4. The manipulations occurred in Sessions 2 and 3.

In the SGAP-I condition, the SGAP task was implemented in Session 2. Students were given a word problem with two unknown variables and asked to generate an analogous problem that involved three unknown variables. In the instruction phase (Session 3), the teacher presented the step-by-step procedures on how to formulate a system of linear equations for a word problem with two unknown variables. She then showed another worked example and compared the two problems to highlight their similarities and differences. The participants

then practiced on four new word problems (all with two unknown variables). The answers were given at the end of the session. For the TGAP-I condition, the TGAP task was implemented in Session 2. Students were given two word problems with the same context; one involved two unknown variables and the other three unknown variables. Rather than generating analogous problems, they identified the similarities and differences between the problems. In Session 3, the same instruction was received as in the SGAP-I condition.

The I-SGAP and I-TGAP conditions were similar to the respective SGAP-I and I-TGAP conditions, except that the instruction was given in Session 2 and the generative task (SGAP or TGAP) in Session 3. To minimize teacher effects, the same teacher taught the instruction phase in all conditions. Similarly, the same researcher and teacher jointly facilitated all the SGAP and TGAP tasks. All participants were also given the same generic training on analogies, which was not specific to mathematics.

Data analysis and initial findings

The descriptive statistics for the PSLE and pre- and posttest scores are presented in Table 1. '

Table 1: Summary of PSLE, AR ability, pretest, and posttests

	Max Score	SGAP – I		TGAP – I		I – SGAP		I – TGAP	
		M	SD	M	SD	M	SD	M	SD
PSLE	300	262.1	4.93	258.3	7.74	263.5	4.65	260.2	5.27
AR ability	16	8.56	2.93	8.17	2.93	9.62	2.90	9.03	2.63
Prior algebraic knowledge	90	40.60	19.41	38.10	13.73	47.33	19. 16	39.85	15.43
Posttest–Learning	50	28.36	7.83	24.62	8.86	27.23	8.66	26.35	8.75
Posttest–Conceptual knowledge	30	9.60	8.16	5.24	7.64	9.08	8.88	9.29	8.42
Posttest–Transfer	60	20.36	8.47	17.02	8.54	24.12	9.88	22.06	8.63

SGAP: Student-Generated Analogous Problems; TGAP: Teacher-Generated Analogous Problems; I: Direct Instruction

We conducted a One-Way ANOVA to test the mean differences in prior knowledge across the four conditional groups. There were no significant difference in AR ability, $F(3, 107)=1.308$, $p=.276$, nor prior algebraic knowledge, $F(3, 107)=1.512$, $p=.216$. There was a difference in PSLE, $F(3, 107)=4.027$, $p=.009$.

We conducted a two-way MANCOVA with posttest scores on learning, conceptual knowledge and transfer as the three dependent variables, pedagogical sequence and generative task as the two factors, and PSLE, AR ability and prior algebraic knowledge as the covariates. The data analysis revealed that pedagogical sequence, generative task and their interaction did not have overall multivariate effect (Wilk's Λ from .95 to .984, p from .153 to .642, partial η^2 from .016 to .050). To inform future studies, the data were explored further. Some speculations from this exploration are discussed in the next section.

Conclusion and discussion

This study investigated the *Productive Failure* phenomenon by testing the effects of (a) pedagogical sequence and (b) degrees of freedom of generation in a task via analogical problem posing, thereby extending prior work, using a 2x2 experimental design. We used PSLE, AR ability and prior algebraic knowledge as covariates for the following reason. Prior research on *Productive Failure* and analogical transfer suggests that such measures of prior knowledge/ability affect learning and transfer. In particular general academic ability (in our study, PSLE score), domain-free general ability (e.g., AR ability), and domain-specific knowledge (e.g., prior algebraic knowledge) have shown effects on post performance, thus, we deemed it important to include these in our model.

A two-way MANCOVA test did not reveal any significant multivariate effect of the two factors or their interaction. From the data exploration, we speculate that the participants' prior knowledge/ability (e.g., prior algebraic knowledge, PSLE and AR ability) might have had strong enough effects on learning and transfer that they possibly overshadowed any effects of the conditional manipulation. Another interpretation is that the learning mechanisms manipulated by the two factors were not strong enough to be detected. For example, while pedagogical sequence, generative task and their interaction did not have overall multivariate effect (Wilk's Λ from .95 to .984, p from .153 to .642, partial η^2 from .016 to .050), prior algebraic knowledge had strong multivariate effect (Wilk's $\Lambda=.826$, $p=.000$, partial $\eta^2=.174$). If this speculation is true, it suggests that compared to the problem-posing task examined by Kapur (2015), an analogical problem posing task might be weaker in enacting learning and transfer mechanisms. The speculation will be examined when we analyze the artifacts generated by the participants in the SGAP and TGAP tasks.

The relative low reliability of the instruments, especially the posttest instruments on learning (Cronbach's α =.55) and transfer (Cronbach's α =.60), might have also made it difficult to detect any learning and transfer effects that were induced by the two factors. For example, in our data exploration, we conducted the pair-wise comparison between SGAP-I vs TGAP-I with prior algebraic knowledge as a covariate. The univariate analysis showed a main effect of generative task on conceptual knowledge ($p=.051$, partial $\eta^2=.073$) with SGAP-I condition outperforming TGAP-I condition. In this model, the variance could be explained by the factor (b) generative task, but the overall univariate model was not significant ($p=.144$, partial $\eta^2=.073$). Thus, we will improve the reliability of the instruments in our future studies.

Another reason for the non-significant multivariate effect could be the profile of our participants. The participants in this study were from an all-girls high-achieving school. It is possible that differences in outcomes could not be detected due to a strong effect of their high prior ability. We aim to conduct future studies using a more general population of students (i.e., represented a range of ability levels) to test this effect.

In summary, we attempted to extend the *Productive Failure* design by replacing the problem solving task with analogical problem posing tasks. The data did not show an overall multivariate effect of pedagogical sequence and generative task. This could due to multiple reasons, such as how strongly the learning mechanisms were enacted, how reliable the instruments were, and how high-achieving students' prior ability influenced their learning. In our further analysis, we will examine the types of analogical problems and analogical mappings generated by the participants in the four conditions to understand the mechanisms enacted by each conditional group.

Endnotes
(1) The SGAP-I and TGAP-I groups were hosted in a lecture hall and the I-SGAP and I-TGAP groups in a computer lab.
(2) The national exam is called the Primary School Leaving Examination (PSLE). The PSLE result refers to the T-score, the relative rank of a student's performance compared to all the other students in the whole cohort.

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Acknowledgments

The Effect of Scaffolding on the Immediate Transfer of Students' Data Interpretation Skills Within Science Topics

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Abstract: Cultivating science inquiry skills is increasingly seen as important to students' science literacy and effective scaffolding can support productive and successful inquiry practices. In this paper, we examine the evaluations of data interpretation practices of students who conducted inquiry within Inq-ITS, an intelligent tutoring system for science. We trace students' progress on data interpretation tasks to a new science topic after having received scaffolds that assist with the procedural aspects of data interpretation. Results show that, overall, after receiving data interpretation scaffolds within the system, students were more skilled at interpreting data in the new topic. However, there were still certain aspects of data interpretation with which students experienced difficulty after receiving the scaffolding.

Introduction

Developing explanations is a key inquiry practice in national science standards and is seen as essential for fostering students' science literacy (McNeill & Krajcik, 2011). Toulmin's (1958) model of argumentation identifies three aspects of explanation: the use of claims, evidence, and reasoning; others concur (Gotwals & Songer, 2009). Students often have difficulties with science argumentation practices, such as using appropriate and sufficient data and providing reasoning for their claims (McNeill & Krajcik, 2011). Other research has shown that students: may not link their data to their claims (Schunn & Anderson, 1999), change ideas about causality (Kuhn, Schauble, & Garcia-Mila, 1992), do not relate outcomes of experiments to the tested theories (Schunn & Anderson, 1999), and rely on theoretical arguments rather than evidence (Schunn & Anderson, 1999). These previous studies have used either verbal protocols or written responses to measure and address these difficulties, but, important to our work, have not lead to scalable support for inquiry practices requiring claims, evidence to support claims, and reasoning linking claims to evidence. Creating assessments of these skills is a critical yet challenging task (McNeill & Krajcik, 2011) because coding the types of data collected through verbal protocols and written responses is labor-intensive and requires the use of inquiry progressions and rubrics (e.g. Gotwals & Songer, 2009; McNeill & Krajcik, 2011). Supporting students in the development of this form of inquiry is also critical and challenging (Gotwals & Songer, 2009). The use of computer-based support may help facilitate this by automating the assessment and delivery of scaffolds, but there has been a lack of research examining either how these explanation practices can be assessed and supported or how computer-based scaffolding can help foster students' development of these skills over time (Windschitl, 2000).

The goal of this study is to use real-time scaffolding integrated into Inq-ITS, Inquiry Intelligent Tutoring System (Gobert et al., 2013b; inqits.org), to foster the development of the inquiry practices of data interpretation and warranting claims, which, to us, underlie argumentation practices necessary for communicating science findings. Secondly, we evaluate how well students can transfer these data interpretation practices to a new topic after receiving scaffolding via our pedagogical agent, Rex, a cartoon dinosaur. We address the question of whether scaffolding has a positive effect on data interpretation by looking at students' performance on a task in a new physical science topic immediately following scaffolding (Sao Pedro et al., 2012).

Transfer and scaffolding of inquiry skills

One way to provide support for the acquisition and transfer of inquiry practices is through the use of scaffolds. When students are having difficulty with inquiry, scaffolds can help them achieve the success they could not on their own (Kang, Thompson, & Windschitl, 2014; McNeill & Krajcik, 2011). Specifically, scaffolds that are developed to address specific aspects of scientific inquiry on a fine-grained level can help students receive the help they need and target the exact sub-skill on which they are having difficulty. Furthermore, scaffolding approaches that react in real-time within a computer environment can provide scalable guidance and support the development of inquiry skills by automatically detecting problems with inquiry (Sao Pedro et al., 2013; 2014), contributing to a deeper understanding of the content and inquiry processes.

Inq-ITS

Inq-ITS is a web-based science environment that assesses and scaffolds middle school students' inquiry skills (NRC, 2011) in real time as they experiment with interactive simulations for Physical, Life, and Earth Science. Within each activity, students conduct inquiry by articulating a testable hypothesis, "experimenting" by collecting data, and interpreting data. In this paper, we focus on inquiry activities for two Physical Science topics: Density and Free Fall. The activities in the Density microworld aim to foster understanding about the density of different liquid substances (water, oil, and alcohol). The activities in the Free Fall microworld aim to foster understanding about the relationship between a ball's mass, initial and final kinetic and potential energy, or its final speed and acceleration, when it is dropped from different heights.

A key aspect of the system is its capacity to provide an assessment of students' inquiry practices based on the processes a student follows and the work products created. The system uses knowledge-engineered and data-mined rules to evaluate log files generated from student interactions within the microworlds as a measure of student performance. Inq-ITS has been shown to be an effective method for assessing inquiry skills in authentic scenarios (Gobert et al., 2013b). For data interpretation, these assessed skills are:

- Selecting correct IV for claim
- Selecting correct DV for claim
- Correctly interpreting the IV/DV relationship
- Correctly interpreting the hypothesis/claim relationship
- Warranting with controlled trials
- Correctly warranting the IV/DV relationship
- Warranting the claim with more than one trial
- Correctly warranting the hypothesis/claim relationship

Inq-ITS can also deliver scaffolds to students in real time via a pedagogical agent. Prior work in Inq-ITS (Sao Pedro et al., 2013; 2014) has shown that scaffolding can help students both acquire and transfer two data collection practices that students did not know at the onset of the study. The data interpretation scaffolds used in Inq-ITS are designed to address four categories of procedurally-oriented difficulties that hone in on the sub-skills underlying data interpretation to provide targeted support for students' specific difficulties (Moussavi et al., 2015). These data interpretation scaffolding categories are: (1) The claim IV/DV does not match the hypothesis IV/DV; (2) The trials selected for warranting are not properly controlled; (3) The claim does not reflect the data selected; and (4) The claim is incorrect as to whether it supports/ does not support the hypothesis.

Methodology

Data was collected over the course of students' interactions in two virtual labs in Inq-ITS.

Participants

Data was collected from 23 8th grade students from the same school in Massachusetts. All the students had previously used Inq-ITS, but not with its scaffolding component.

Procedure

Topic 1: Density

Students completed the density activities in their science classroom after the content had already been introduced in the class. There were three activities. The first activity had no scaffolding support so as to record baseline data of students' inquiry practices. For the next two activities, students received scaffolding support in hypothesizing, data collection, and data interpretation. While the focus here is on the data interpretation scaffolding, it was important that students be scaffolded throughout the inquiry process because students must have a testable hypothesis and have collected appropriate data before they can try to correctly analyze the data and create a claim.

Topic 2: Free fall

This set of activities took place three weeks after the activities in topic 1. Students completed the free fall activities in their science classroom. Students had not yet learned about the content presented in these activities and as such, these activities served as a sort of content pre-test. No scaffolding support was present for any student throughout these activities.

Data analysis

The skill evaluations generated from the assessments within Inq-ITS (as described above) were examined for immediate skill transfer (Sao Pedro et al., 2012). To analyze transfer, we first looked at students' *first chance* to demonstrate the various data analysis practices in the second topic (Free Fall). This allows us to get an initial look at the students who received data interpretation scaffolding in the first topic to see if it had a positive impact on the transfer of data interpretation practices across topics. If scaffolding had a positive impact on data interpretation skills, we would expect to see more students demonstrating the skills correctly in the second topic than in the first.

Findings

Results from this analysis (see Table 1) showed that for 6 out of 8 of the data interpretation skills evaluated, at least 50% of the students demonstrated the skill correctly on their first try in topic 2. The three skills that the highest percentage of students demonstrated correctly on their first try in topic 2 were: selecting the correct DV for the claim, selecting the correct IV for the claim, and warranting the claim with more than one trial. The two skills that less than 50% of the students demonstrated correctly on their first try in topic 2 were: correctly interpreting and correctly warranting the claim/hypothesis relationship.

Table 1: Students' progress in topic 2

Evaluated Data Interpretation Skill	Students demonstrating skill correctly in topic 2		Students demonstrating skill correctly in topic 2 after demonstrating incorrectly in topic 1		
	# of students (out of 23)	% of students	# of students incorrect in Topic 1	Number of students that got skill correct in Topic 2	% of students
Interpreting the IV/DV relationship	12	52.17%	14	6	42.86%
Selecting correct DV for claim	21	91.3%	8	7	87.5%
Selecting correct IV for claim	20	87%	2	1	50%
Interpreting the hypothesis/claim relationship	10	43.48%	15	6	40%
Warranting with controlled trials	13	56.52%	10	2	20%
Warranting the IV/DV relationship	12	52.17%	14	5	35.71%
Warranting the claim with more than one trial	20	87%	6	3	50%
Warranting the hypothesis/claim relationship	10	43.48%	15	5	33.33%

To get a closer look at how scaffolding is affecting the transfer of skills, we took a second look at the data, this time using only students who did not correctly demonstrate the skill on their first try in topic 1. This will ensure that we do not include students who may have already known the skill prior to using the microworlds and instead focus on the students who are acquiring the skill through the support of the scaffolds. These results showed that some degree of acquisition and transfer of skill was evident for all data interpretation skills. The three skills that the highest percentage of students demonstrated correctly on their first try in topic 2 were: selecting the correct DV for the claim, selecting the correct IV for the claim, and warranting the claim with more than one trial. The two skills that the lowest percentage of students demonstrated correctly on their first try in topic 2 were: warranting with controlled trials and correctly warranting the claim/hypothesis relationship.

Conclusion and implications

Our findings showed that, after scaffolding, students were better able to create a claim (focusing on the appropriate IV/DV) and choose more than one piece of evidence to warrant their claim, two previously documented areas of difficulty for students (McNeil & Krajcik, 2011; Schunn & Anderson, 1999). This suggests that our targeted scaffolding, which provides real time help when students need it, can help students with difficult practices underlying explanation.

Our findings also showed that students continued to struggle in the new topic with warranting claims with controlled trials and correctly interpreting/warranting the claim/hypothesis relationship. The difficulty with warranting claims with controlled trials may be linked to another known difficulty students have with science inquiry – collecting data with controlled trials (Sao Pedro et al., 2012) and may therefore be a more persistent difficulty needing more scaffolding support. The student behavior surrounding the difficulty with interpreting and

warranting the claim/hypothesis relationship is less clear, as not much research has been conducted on this particular skill. While students may be asked to provide a rebuttal of a different claim (with qualifying evidence and reasoning) once they have made their own claim (e.g. McNeill & Krajcik, 2011), students are rarely asked to definitively give a statement about whether or not their claim supports or refutes their original hypothesis. Further research is needed to address why students have difficulty with this, but it is possible that the acquisition of this skill is impeded by students experiencing confirmation bias and having a disinclination to abandon a favored hypothesis despite having interpreted their evidence to come up with a different claim (Klayman, 1995).

Conceptualizing and supporting the components of the explanation framework – claim, evidence, and reasoning – in an automated and fine-grained way with appropriate sub-skills can help us unpack and target known difficulties documented by previous research (Gotwals & Songer, 2009; McNeill & Krajcik, 2011; Schunn & Anderson, 1999). This work shows that scaffolding these data interpretation practices in real-time can be a beneficial way to aid students in both acquiring and transferring these skills to new science topics, even when students may not have initial content knowledge in that topic. This work also shows that students can have persistent difficulty with regard to classifying the relationship between a claim and a hypothesis (i.e. saying if the claim supports or refutes an initial hypothesis), suggesting that this skill may be more difficult for students to acquire and transfer and may, therefore, need more scaffolding support.

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Exploring the Relationship Between Gesture and Student Reasoning Regarding Linear and Exponential Growth

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Abstract: Leading middle school students to effectively reason with magnitude, small and large-scale quantities, and linear and exponential growth is a challenge facing science teachers in the U.S. working to implement the NGSS and its associated focus on crosscutting concepts. This paper examines the relationship between middle school students' gestures and their reasoning about quantitative growth. For this study the authors developed interview protocols on several topics that involve numbers increasing linearly and exponentially. Students' verbal and gestural responses during the interviews were transcribed, coded, categorized and analyzed. Results showed that students display a breadth of context-dependent gestures, that their verbal reasoning is associated with the type of gesture they produce, and that gesture-speech mismatches are present in middle school students' reasoning about scale. Implications of this study include design guidelines for an interactive system that standardizes and structures scale-related gestures.

Keywords: quantitative growth, student gestures, gesture-speech mismatch

Introduction

There is strong support from multiple disciplines for the notion that gestures facilitate processes of thinking and learning (Roth, 2001), and there is building evidence that gestures can promote learning of specific ideas in STEM (e.g., Alibali & Nathan, 2012; Goldin-Meadow, Cook, & Mitchell, 2009). Some have argued that even abstract concepts in STEM come from our embodied interactions with the world (Lakoff & Nunez, 2000). In this paper we examine the notion of quantitative growth and how students make sense of increasing numbers and strategies for "scaling up" through verbal and gestural communication. In particular, we are interested in the ways in which gestures support or hinder student reasoning about large quantities in their efforts to solve scientific problems.

Several topic areas in science require students and practitioners to engage with increases in quantity and different types of scales (e.g., liner, exponential, logarithmic, etc.). Reflecting this multidisciplinary aspect, *scale, proportion, and quantity* are highlighted as crosscutting concepts in the Next Generation Science Standards in the U.S. (NGSS Lead States, 2013). And yet, research suggests that students across the K-12 curriculum often struggle with reasoning about and executing operations involving very large numbers (Tretter, Jones, & Minogue, 2006).

In this study we seek to gain greater insight on the challenges that students face when reasoning about increasing quantities, and whether or not the gestures students make during this type of reasoning appear to play a role in their thinking and learning. Specifically, the following questions are investigated: 1) What are the different ways by which students use gestures to convey their scientific reasoning of topics related to growth? 2) How does the context of the gesture (i.e., problem solving or communication) seem to affect the type of gestures students utilize?

Symbolic and concrete gestures

Figure 1. (left) A Symbolic gesture (right). A concrete gesture.

Studies of hand gestures have indicated that these embodied acts do more than simply echo verbal expressions; rather they are "symbols that exhibit meanings in their own right" (McNeill, 1992, p.4). The form of a gesture can vary depending upon the purpose of communication (Crowder, 1996). For the sake of examining gestures related to quantitative reasoning, we distinguish between symbolic and more "concrete" gestures. In this study, symbolic

gestures are a representation of operations and/or numerical values, such as holding up fingers to represent a certain quantity (see Figure 1, left) or crossing two fingers to make an 'X' representing multiplication. Alternatively, concrete gestures represent objects or express ways that objects are manipulated (Figure 1, right). For example, placing one hand on top of the other to represent doubling as an operation, which adds a quantity to itself.

Methods

Participants
Fifteen (10 males and 5 females) middle-school students were interviewed for this study. Students came from different backgrounds from the surrounding area of a large Midwestern University in the United States. Student interviews were videotaped to aid in the analysis.

Instrument
This study employed semi-structured, task-based interviews involving problems about linear and exponential scales. This first question posed to students was a modified version of the 'grains of rice on a chessboard' problem, an exercise commonly used to teach exponential growth. In this version of the problem, students were asked to imagine that they had won a prize and were asked to choose whether they would prefer an option where they received $1000 per day for 30 days, or a second option where they received $1 on the first day and double the amount of the previous day, each day, for thirty days. Students were asked to choose one of the options and explain why they selected the option. They were then asked to explain how the total amount of money increased each day for both options. If students did not spontaneously use gestures in their explanations, they were prompted to gesture or act out how each option increased. Finally students were asked how they would convince a friend to choose the second option if they could not communicate verbally. In addition to facilitating a transition to having students think about different types of scales in various science contexts, this problem provided insight into how a participant makes sense of increasing quantities and the gestural resources they have available for thinking and communicating about them. After this initial question, three base problems contrasting linear and exponential growth were posed to the participants from various science domains, which employ different scales (e.g., The Richter scale, geologic time, population growth, etc.). Our analysis here focuses primarily on student reasoning about the initial question.

To analyze students' quantitative reasoning and gesture, we segmented the videos according to where a gesture related to describing a quantity that has increased or how it is increasing took place. Included in the segmentation of the video interviews was a detailed description of how the hands, fingers, etc. were employed in the gesture, as well as a transcription of the speech accompanying the gesture. Once coding of data was complete, students' gestures were categorized. Two raters categorized student reasoning and gestures with an initial 70.4% agreement. The raters then met to discuss problems on which there were disagreements in the ratings and to see if some common, agreed-upon rating could be reached. Following discussion 100% agreement was reached.

Analysis
Frequencies for each gesture category were computed for all participants and are shown in Table 1. The speech associated with each gesture act was coded for whether or not it showed correct reasoning, in the sense that it accurately described the mathematic relationships present in the problem. Additionally, each gesture was coded for whether it was aligned with the concurrent speech (i.e., did both the speech and the gesture appear to be describing the same quantity or relationship?). Table 2 shows frequencies for the different combinations of reasoning and alignment: (1) correct verbal reasoning on mathematical growth with aligned gesture, (2) correct verbal reasoning with an unaligned gesture, (3) incorrect verbal reasoning with an aligned gesture, and (4) incorrect verbal reasoning with an unaligned gesture. Note that alignment of the gesture was coded with respect to both alignment with correct reasoning and alignment with student verbal reasoning.

In order to examine further the first research question, a Fisher's exact test between students' gesture type (concrete vs. symbolic) and the alignment of their gestures with their reasoning on mathematical growth was conducted. The frequency table can be found in Table 3. To answer the second research question, a Chi-Square test of independence was used to investigate the association between the type of gesture used by the student and the context of the question (whether a student spontaneously gestures or whether s/he is prompted to gesture).

Results

In the context of the quantitative growth problem, students generated a total of 161 gestures. Table 1 shows the most used gesture ($N = 44$) was the symbolic gesture of using fingers to indicate numbers or mathematical symbols (Figure 1 left). Conversely, there were only 5 instances of gestures indicating exponential growth by using a hand to show the curve of an exponential graph. Other commonly used gestures included different ways by which students represented stacking or used a referent, which they manipulated to indicate growth.

Table 1: Student gesture categories and frequency

Gesture Category	Total	Gesture Category	Total
1. Fling hands and/or fingers to show a random increase	14	5. Adding from one hand to another to indicate an increase in the form of stacking	29
2. Using fingers to indicate numbers, numerical or mathematical symbols	44	6. Vertical/horizontal parallel hands to show a certain amount	25
3. Vertical/horizontal parallel hands to show a linear increase	20	7. Wide arms spread gesture	6
4. Using hand as a curve for an exponential growth	5	8. Placing a referent in different places to represent time and growth	13
		9. An iterative process to indicate increase	5

Table 2 below shows that the vast majority of students' gestures (129 out of 161) revealed correct reasoning about mathematical growth and produced gestures aligned with their reasoning. An interesting finding was that 15 out of 161 gestures revealed cases where although students incorrectly reasoned about mathematical growth, their gestures matched the correct reasoning. For example, Kathy (pseudonym) incorrectly articulates her reasoning about doubling. According to her verbal statements, doubling is adding 2 to the initial amount. As she makes this statement, however, she produces a series of gestures where she uses her hands to set a fixed amount, and then she systematically extends the distance between her hands to twice the initial amount. This gesture-speech mismatch was evident in 15 places in which students' verbal reasoning (speech) is incorrect but their gestures are indicative of (aligned with) the correct reasoning. This finding is in line with previous research showing gesture-speech mismatches as an index of transitional knowledge (Perry, Church, & Goldin-Meadow, 1992).

Table 2: Students' levels of sophistication

	Correct Reasoning	Incorrect Reasoning	Reasoning Not Applicable	Total
Gesture and Reasoning Aligned	129	15	3	147
Gesture and Reasoning Unaligned	4	5	2	11
Alignment Not Applicable	0	0	3	3
Total	133	20	8	161

Fisher's exact test between students' gesture type (concrete vs. symbolic) and the alignment of their gestures with their reasoning on mathematical growth was conducted. The test revealed significant relationship between gesture type and alignment ($\chi^2_c(4) = 14.58$, $p < .05$). Specifically we found that concrete gestures are more likely to be aligned with correct reasoning than symbolic gestures in this problem-solving context. In addition, a pair-wise test of correlation shows that there is a significant positive association ($p < .05$) between gesture type and alignment. This suggests that the use of concrete gestures may be indicative of more correct reasoning when describing quantitative increase. We make the observation that even though symbolic gestures were more common, concrete gestures had a stronger association with correct reasoning in topics related to growth.

Table 3: Relationship between students' type of gesture and the gesture alignment with reasoning

Alignment	Gesture Type			
	Concrete	Symbolic	Concrete and Symbolic	Total
Aligned	96	27	24	147
Unaligned	9	2	0	11
N/A	0	3	0	3
Total	105	32	24	161

To answer the second question, an examination of the relationship between gesture type and the question context was examined. The questions either asked students to explain their reasoning or to try and communicate a specific quantity or quantitative operation to another person (e.g., how would you show someone 'doubling' non-verbally). Table 4 shows the result of the Chi-Square test of independence revealed an association between the type of gestures used by students and the context of the question (χ^2 (4) = 35.36, $p < .01$). Specifically, students were more likely to produce concrete gestures when they were engaged in reasoning, and more likely to produce symbolic gestures when engaged in communication about specific quantities or operations.

Table 4: Relationship between students' type of gesture and the gesture alignment with reasoning

Context	Gesture Type			
	Concrete	Symbolic	Concrete and Symbolic	Total
Reasoning	59	3	2	64
Communication	45	32	20	97
Total	104	35	22	161

Conclusions and implications

We make the following inferences from the findings of this study: (1) Concrete gestures were more common in reasoning (as opposed to communication) acts. In addition, when using these concrete gestures for reasoning, students' reasoning was accurate in almost all cases (2) The variation of concrete gestures seems to provide students with multiple potential pathways for doing their reasoning, whereas symbolic gestures only give a constrained set of numbers and operations (3) Gesture-speech mismatch exists in the context of middle school students reasoning about increasing quantities. Further research is needed on whether these mismatches can be leveraged as transitional points in the learning trajectory for students' understanding about scale and magnitude.

Students used a breadth of gestures to reason and communicate about growth. A meaningful pattern in communications about increasing quantities was evident in this study. This implies that in topics such as mathematical growth, we can benefit from a system that standardizes and structures this pattern. Finally, we think that students may benefit from opportunities to use more concrete gestures, but in a more structured and consistent way. This study gave us many ideas for the kinds of gestures that might be incorporated into a gesture recognition interface. In fact, our research team is currently in the process of building a prototype interface that allows students to define and use concrete gestures for reasoning about problems across science topics.

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Sketching a Pathway Through Design Worlds: Multimodal Communication in a Fifth-Grade Collaborative Engineering Project

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Abstract: This qualitative case study sought to understand how disciplinary literacy practices associated with engineering design were used to facilitate communication among the four fifth-grade members of one collaborative learning group engaged in brainstorming initial design ideas for a remote-controlled, paddle-propelled robotic watercraft. Specifically, we focused on understanding how sketching was used by group members and for what purposes. Analysis of nine student-generated sketches and discourse during the team's first work session suggested that sketching was "mixed and mashed" with other literacy acts to create design worlds, facilitate deep learning, and navigate pathways towards engineering goals.

Introduction

The purpose of this study was to understand the role of disciplinary literacy practices to facilitate communication in engineering design work by investigating the ways fifth-grade students use sketches and sketching to construct knowledge, identify with the domain, and navigate pathways towards collaborative engineering goals (Lemke, 2000; Wilson, Smith, & Householder, 2014). Building on the first author's previous analyses of students' interweaving of virtual and print-based texts when designing physical artifacts (Jordan, 2014), we zoom in on sketches and sketching to investigate the roles that "mixing and mashing" (Jewitt, 2006) of texts play in elementary teams' design processes. Specifically, we focus on one fifth-grade team's creation of and uses for sketches while engaged in collaborative efforts to design, build, and program a remote-controlled paddleboat and achieve assignment objectives.

Current understanding of communication practices within engineering design contexts is limited, particularly for middle grade learners. Yet, communication is an integral part of the design process. Understanding how young adolescents learn to engage in collaborative engineering design practices entails understanding communication processes by which group members come to co-create design projects. In science and engineering contexts, successful communication usually entails the creation and use of multiple and multimodal literacy practices. Thus, understanding communication in learners' design practices requires understanding how they use literacy practices to engage in collaborative interaction during design project work.

Here, we examine the intertextual and multimodal relationships within collaborative interaction in an engineering learning context where learners had time and space to take up positions as drivers of creative products and robust learning. In doing so, we situate disciplinary learning of engineering design practices in the wider context of multiliteracies learning and design pedagogy.

Multiliteracies communication landscape: Design pedagogies

The communication contexts of the 21st century are rapidly evolving and increasingly diverse, shaping and being shaped by new literacy requirements (Cope & Kalantzis, 2009); engineering design contexts are no exception. As Siegel (2006) noted, "our social, cultural, and economic worlds now require facility with texts and practices involving the full range of representational modes" (p. 65). The current (and seemingly future) communication landscape and attendant literacy practices are increasingly multimodal as technological advances continually merge with new communicative affordances, generating a need for learners to develop communicative competencies in translating, transforming, and coordinating ideas across representational modes (Kress, 2010; Lemke, 2000). Additionally, professional, civic, and social participation norms have evolved toward more informal, self-directed structures. Thus, young learners need to engage in learning experiences that help them develop capacities for participating in cultures of "flexibility, creativity, innovation, and initiative" (Cope & Kalantzis, 2009, p. 133), i.e., *design pedagogy*. Collaborative design projects offer one such experience.

Design pedagogy requires attending to helping students learn to engage in design processes. To do so, they must acquire what Pendleton-Julian and Brown (2011) called design literacy as a "new instinct" to meet the educational needs of the 21st century. Design literacy entails the capacity to rapidly reiterate potential solutions in problem-solving settings, expand on brief specifications of problem, cope with the intensely public and personal experience of critique by understanding critique as a mechanism for linking thought and action, and orchestrate ambiguity that is inherent to design processes. Such processes are communication rich.

Design is communication-rich activity; communication plays critical roles in engineering design endeavors (NRC, 2011). Communication among team members is widely recognized as a fundamental aspect of design (Darling & Dannels, 2003; Sonnenwald, 1996). Learning to design requires learning to cope with communication challenges associated with collaboration (Jordan & Babrow, 2013, Jordan & McDaniel, 2014). Furthermore, design entails not only communication with people, but also "conversation with materials" (Schoen, 1992). Such communication is multimodal in that it entails translating among representations, particularly through sketching (Geisler & Lewis, 2000; Stevens, Johri, & O'Connor, 2014). Sketching fills a disciplinary need to communicate in more dimensions to decipher *design worlds* (Schoen, 1992).

Methods

The setting for this study was a regular fifth-grade class in a suburban school district in the southwest US. The 24 ethnically and academically diverse students in the class included 15 girls and 9 boys. Students engaged in three collaborative engineering challenges across the school year, working in three-to-four-member groups and changing membership for each project. The project that was the focus on this study was the third and final and the only design project of the school year. Students were first instructed to individually identify an environmental problem and to brainstorm ideas for addressing that problem through a robotic product. Each student brainstormed in an individual design journal before being assigned to one of six collaborative teams. The focal group whose communication was the object of analysis was comprised of four members, Ida, Bobby, Derrick, and Roy. The analysis described here focuses on data associated with Day 1 of the 14-day project, a conceptual-only session in which prototyping with physical materials took place only in students' imaginations. By the end of the day this team had decided to make a robotic boat to heat and cool a swimming pool and collect debris in a net, combining similar ideas Roy and Derrick had brainstormed separately.

Data sources included the video recording and transcript of the group's first hour-long work session (Day 1 of a 14-session project). Photographs of sketches and other artifacts also informed our interpretations. First, we sequentially analyzed the sketches themselves. Following Cardella, Atman, and Adams (2006), we noted the type of representation of each sketch (creating a new sketch, continuing a sketch, returning to add to a sketch after engaging in a different activity), perspective or vantage point (side, front, back, aerial, underneath, inside, outside), the modes present (e.g., text, numbers, icons, images), and the degree to which it was technical or narrative (using a scale from 1 to 4). We catalogued each image's basic components (number of structures present, connections among structures, details, relationship between structures, and the incorporation of technical components), and the extent to which context was envisioned. Following in the analytic path of Lewis (2000), we matched sketches to their in-context use to understand the interplay between the characteristics of sketches and the processes and functions of sketching practices. We identified which group members initiated and contributed to each sketch and when they were created in the sequence of design decisions that unfolded across the work session. We also tried to discern for what purposes they were created.

We then analyzed discourse from the collaborative work session in which the sketches and other multimodal texts were created and used in order to understand what ideas team members took up, how they took them up and to what effect. We drew from methods of mediated discourse analysis (Scollon, 2001) to understand the "cultural learning and social effects" to learners "actions with materials" as meditational means, tools with which individuals participate in social practices (e.g., designing, negotiating, sketching) using material resources (e.g., paper, pencil) to craft communicative messages. Through analysis of the discourse surrounding acts of sketching in conjunction with the transformation of sketches, we interpreted what was being designed, what ideas were created, kept, or discarded along the way, how sketching influenced members thinking about their design purpose and constraints, and how it supported and shaped communication.

Findings

The four members of this fifth-grade engineering design group engaged in rich communicative work in their pursuit of a design goal; various acts of literacies were integral to that process. Throughout the design process, students mixed and mashed fragmented and partial literacy acts to build pathways between independent and collaborative conceptions of their complex design worlds. No single literacy or text was powerful enough to sustain the evolution of a design project. The evolving engineering design world required students to work through the challenges of understanding their own perspectives as well as their peers' perspectives.

Before the group was even formed, three of its members had created a total of four sketches between them as they responded to their teacher's instructions to brainstorm possible design product ideas in their individual design journals. Bobby sketched a "trash picker-upper", his only idea. Ida sketched a "water consumer" and a "bag recycler", but did not sketch her other idea, a crane operated trash picker upper. Roy sketched a pool heater-cooler with a scoop and a net to clean the pool as a nod to the design specification's call for the product to

address an environmental problem. Of these initial sketches, Roy's was the most technical, the most complex in its depiction of the relationships among structural elements, and the only one to label parts. Bobby's sketch was the only one to include contextual features to help indicate the function of the product and the only one to include two frames to indicate the behavior of the product (i.e., one depicting the arms crushing trash, the other depicting the arms throwing trash into a receptacle). Derrick was the only group member who did not sketch during individual idea generation, choosing instead to create a list of possible design products. Among Derrick's many ideas was an octopus-shaped robot that heats a swimming pool. Once the group was formed, this was the first idea to be shared with the group: "Like, say this is the NXT; it'll be outside the pool and it'll be an octopus floating." This was followed quickly by Roy's exclamation:

> Mine is like the same idea almost! … but instead of just heating the pool, it has a like a heater and a cooler and when it was really hot outside it would cool it and whenever it's cold outside it would heat it for you. But not only will it do that, but it'll have an environmental cause too. It also has a net and a little scooper, so it can pick up trash.

Noteworthy is the different manners in which Derrick and Roy presented their ideas, with Derrick concentrating on structures and aesthetics, and Roy integrating explanation of structures with behaviors and functions of his robot. We hypothesize that Roy's integration and elaboration may have something to do with the elaborated thinking he engaged in through sketching his idea. Although Bobby and Ida shared four additional ideas in quick succession, Roy's suggestion in talk turn 81 to combine his and Derrick's ideas was tentatively taken up, perhaps driven by Roy's suggestion that they "draw a sketch of what it would look like if we combined them."

Over the next 50 minutes, the team created a total of nine more sketches, five were solo-authored by Roy, two were solo-authored by Derrick, and two were collective products of the three boys. Both of Derrick's sketches were more narrative than Roy's, both focused on aesthetic and contextualizing elements of a highly personified design in with the octopus shape of the structure and its facial features figured prominently. Roy's sketches took on more personification elements and more contextualizing elements across time. It is perhaps important that the two primary sketchers were Roy and Derrick, who were also the co-originators of the pool heater-cooler idea. Perhaps their authorship carried authority that made sketching those ideas their domain.

The evolution of the team's design ideas was captured in these sketches and these same ideas were reflected also in the group's talk. However, additional ideas were introduced in talk but were not captured the sketches. This is because the use of meditational means and materials varied among the four students. Although Bobby did not initiate any sketches and only contributed to two collective sketches, he nonetheless contributed substantive design ideas. The same can be said of Ida, though she did not sketch anything after being assigned to her group. Three shared aspects of Ida and Bobby's contributions are noteworthy. One is that both Ida and Bobby chose to contribute design ideas using a combination of verbal description, gesture, and manipulation of physical objects to represent structural elements of design ideas (e.g., pencils, books) rather than to depict ideas in sketches. The result of this choice was that their ideas were more ephemeral than the ideas depicted in sketches, and few of those ideas made it into the sketches initiated by Roy and Derrick. Another shared aspect of their contributions was that both modified elements of their own original designs for trash picker uppers, morphing them to apply to the pool cleaner robot the group decided to pursue. Ida proposed a crane to transport collected trash to shore and Bobby proposed a swinging arm to haul in the net. Bringing these ideas forward into the collaborative design was perhaps a way to integrate their thinking even though the group had not selected their designs. Finally, Ida and Bobby's contributions had the shared quality of persistence. Bobby was repeatedly adamant that the robot must include a net big enough to engulf the bottom of the robot. This idea was eventually incorporated in two sketches and carried forward. Ida was adamant about the need to identify materials and technical elements of the design. Although she did not sketch herself, she used other's sketches as vehicles to question what structures would be made of and how they would work. In this way she contributed substantively to the evolution of the team's design by focusing attention on important design decisions.

The final sketch created during this team's first work session was the only one not initiated by one of the group members. The teacher instead, initiated it following a quick check-in meeting in which team members explained their idea. This sketch, collectively drawn by the three boys, was the neatest among the collection and had the most labeled structures. However, there was little to suggest what materials elements are made of, and many of the elements depicted are aesthetic rather than functional (octopus legs, eyes, mouth, nose). Clear efforts were made to depict relationships among structural elements. Yet, no new design elements were added beyond those in former sketches. Essentially, the teacher initiation of a formal sketch curtailed design ideation.

Conclusions and implications

In the complex space of collaborative engineering design, projects, learners develop multimodal representations of their own design world to engage and co-construct the evolving design world of their collaborative team. Encountering communication challenges, the collaborators in the group observed here reached for self-generated sketches as well as self-generated uses of sketches in order to persist through the design problem. Sketches were integral meditational tools used to communicate with each other and with the design work. In the process of meeting communication challenges team members generated these multimodal resources, working to create their own texts in order to develop understandings, refine ideas, and move their design work forward. Students generated sketches to communicate their design ideas to themselves, advocate for their own ideas, collect design ideas together, and take their work to the next step on a pathway through the design world they were creating.

Learners were doing rich communicative work in the pursuit of a design goal and literacy acts are integral to making that happen. Learners used sketching to facilitate communication with their group members, and with the evolving design. As they negotiated communication challenges in their created design worlds, they interacted with objects available in the environment, using them to, among other things, generate sketches in service of shaping the social and material design worlds they were collectively creating. Sketching served as more than a just design tool; it served as a social glue within the students' co-constructed design world, supporting communication that gave way to collaborative pathways moving the design process forward.

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"Show Me" What You Mean: Learning and Design Implications of Eliciting Gesture in Student Explanations

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Abstract: This paper describes preliminary research conducted on how gestures affect the construction of student explanations of science phenomena. We examine the effect of asking middle school students to "show me" while they construct explanations of critical science topics such as heat transfer and the causes of seasons. Specifically we were interested in whether there were any apparent changes in students' inclusion of unobservable causal mechanisms (e.g., molecular interactions) that underlie observable phenomena such as how heat moves through a metal spoon. To understand these effects, we coded for whether explanations were more mechanistic following the "show me" prompts compared to their previous explanations. Results showed that elicitation of gesturing frequently led to increased attention to, and specification of, the critical mechanisms. We describe a few specific cases to illustrate the ways in which gesturing appeared to alter student reasoning.

Keywords: gestures, explanations, science reasoning, embodied learning

Introduction

Previous research in psychology and the learning sciences has described the critical role that gestures play in thinking and reasoning (e.g., Goldin-Meadow, 2005; McNeill, 1992; Roth, 2001). Frequently studies of gesture and learning have examined how gestures occur naturally in the context of students' reasoning and constructing meaning in areas such as geometry (Kim, Roth, & Thom, 2011), making sense of Cartesian graphs (Radford, 2009), and geology (Singer, Radinsky, & Goldman, 2008). Among other findings, these studies have demonstrated that spontaneous gestures frequently capture a learner's emerging understanding of complex concepts, and that they often precede coherent verbal articulation of canonical ideas. In this preliminary study, we are interested in what happens when explicit attention is given to student gestures through interviewer requests to "show me" as they are in the midst of explaining observable science phenomena (e.g., gas pressure). Leveraging a large corpus of student interviews on three different science topics, we describe how explanations were impacted by gesture prompting. We extracted excerpts of these interviews where gestures were elicited, and we coded these excerpts for whether or not explanations changed from their previous attempt to explain the science phenomenon. Some of the ways that gesturing appeared to impact student reasoning are highlighted through a few illustrative cases.

Gestures and learning

Theories of embodied cognition and embodied learning posit that the composition and activities of our bodies are central to processes of thinking and reasoning (e.g., Glenberg, 2010; Wilson, 2002) and that cognition is "grounded" in simulations of sensorimotor activity (Barsalou, 2008). Gestures are embodied acts that frequently accompany reasoning and problem solving, and several recent studies have shown how gestures play a mediating role in the knowledge-building discourse in authentic learning environments such as classrooms (Alibali & Nathan, 2012; Carter, Wiebe, & Reid-Griffin, 2006; Roth, 2001). Yoon, Thomas, & Dreyfus (2011) describe how gestures performed within a dyad can give rise to new mathematical insights through a space of "virtual constructs," and the authors encourage raising students' awareness of gestures as a learning resource. While studies of gesture and learning are quite prevalent, relatively few studies have examined the effects of explicitly encouraging students to perform gestures while conversing or constructing explanations. In one such study, children who were asked to gesture while working on novel math problems showed stronger performance than their non-gesturing peers (Broaders, Cook, Mitchell, & Goldin-Meadow, 2007). While there seems to be affordances for making student gesturing an explicit component of reasoning and constructing explanations, the different ways that this can occur, and their specific effects on learning, require further exploration.

Study methods and design

This investigation of student gesturing was conducted in the context of a larger project looking at embodied expressions and interactions with science education simulations. The dataset used for this study was a set of individual interviews that were conducted with 37 middle school students from several different schools located in the Midwestern United States. The primary objective of conducting these interviews was to gain insights on student explanations of phenomena related to three science topics: gas pressure, heat transfer, and the causes of seasons. Most students were interviewed about two topics, for a total of 24 interviews on each of the three topics that lasted approximately 25 minutes each. In these interviews students were asked to give explanations multiple times, including an explanation at the beginning of the interview and one at the very end. Over the course of the interviews, students were also asked to make predictions, view computer simulations, and represent their ideas with drawings and gestures. Students were prompted to use gestures in several ways, including being asked to repeat a gesture that they had used previously, or being asked to use a specific gesture (e.g., "let your fingers be the molecules…"). The most common way that gestures were prompted, however, was by the interviewer asking the participant to "show me" while they were in the midst of giving an explanation. Students almost always understood the "show me" prompt as a request to use hand gestures, but if any confusion was expressed the interviewer would follow-up by asking if they could use their hands. The "show me" prompt typically came when students were attempting to describe, or were hinting at the core causal mechanism of the phenomenon. For example, in the gas pressure interviews students were asked to explain why a plastic syringe with the end blocked off could only be pushed down partially, and that when one lets go the plunger pushes back out again to its starting point. Students frequently understood that the air inside the syringe consisted of molecules, but they often struggled with describing what those molecules were doing that led to the pressure that pushes out the syringe.

Interviews were video recorded, and audio from the interviews was transcribed. Transcripts were divided into explanatory segments, which were portions of the interview when students were asked for explanations or when they offered explanations without being prompted. A subset of the explanatory segments were used as the unit of analysis in this study. Specifically, we selected explanatory instances (a) near the end of the interview when students had been exposed to some resources that may have helped them develop their explanation, and (b) when they were asked to "show" the interviewer what they were trying to convey, or an otherwise explicit request to utilize gestures in their explanations. This resulted in 14 explanatory instances for the gas pressure interviews, 16 instances for the heat transfer interviews, and 17 instances for the seasons interviews. Each of these 47 instances were reviewed on video and independently coded by two members of the research team. Because we were particularly interested in the inclusion of causal mechanisms, explanatory segments were coded for whether or not the explanations were "more mechanistic", "less mechanistic", or if there was no change compared to the most previous explanation that the student had given. By mechanistic, we refer to whether the explanation explicitly describes the causal mechanisms for the phenomenon they are engaged with. For example, with the causes of seasons, we were interested in the degree to which the students described how the Sun's rays came into contact with the surface of the Earth (straight on, at an angle, etc.) at various points in its revolution around the Sun. We took note of the degree to which they discussed how the angle of contact affects the density of the light rays and subsequently the amount of heat transmitted to a given part of the Earth. If this mechanism was made more explicit and stated more clearly relative to the last time they gave an explanation of the same phenomenon, then the instance was coded as "more mechanistic." In their first pass of coding the instances, the two coders had 61% agreement. Discrepancies in coding were resolved through discussion until consensus was reached and all 47 instances were assigned a single code.

Results: Gesture prompting and types of mechanistic changes

In order to get a general sense of whether or not prompting students to use gesture had an impact on their explanations, we tallied how many of these instances resulted in improved focus on mechanism. Table 1 shows the breakdown by interview topic area. Looking across all the interviews a total of 28 or 59.6% of the instances of gesture prompting were deemed to have more mechanistic reasoning compared to their previous explanation. A total of 18 or 38.2% were judged not to have changed, and only one instance was coded as being less mechanistic than the previous explanation. The basic finding from this analysis is that across multiple topics in science, simply prompting a learner to "show me", or to incorporate gesture into their reasoning, frequently led to higher engagement with the core mechanism in their explanations.

The precise reasons why gesture leads to more focus on mechanism is not readily apparent and will require further study, but a few examples provides some insights about the kinds of changes the gesture prompts elicited. In our first example, prompting a student to use gesture seems to lead him to be explicit about the mechanism of heat transfer in a metal spoon (i.e., fast moving molecules speeding up slower moving molecules via collisions). In this example, Harun has just given an explanation of why one end of a metal spoon gets hot

Table 1: Changes in the number of mechanistic elements in explanations after being prompted to gesture

Topic	Explanations became less mechanistic	No change	Explanations became more mechanistic	Total
Gas pressure	1	5	8	14
Heat transfer	0	5	11	16
Seasons	0	8	9	17
Total	**1**	**18**	**28**	**47**

when the other end has been submerged in boiling water. He talks about molecules vibrating and that heat moves through the spoon, but does not say specifically how the heat moves. Later in the interview the following exchange occurs:

> **Interviewer:** So, can you show me with your hands how the heat is going from the hot to the cold [side]?
>
> **Student:** Okay. This is the … hot side. And this is the cold water. And the hot side vibrates starting to travel to the spoon. And then, on the cold tip, when the hot side collides it's starting to get hot.
>
> **I:** So when you were doing this, was this, was your hand a molecule? Or was it, was it something else?
>
> **S:** It was molecules. And when it starts to vibrate because it's heating up then the other ones in the middle start to vibrate too. And then it starts to vibrate until it's completely warm.

When asked to show the spoon, Harun held his hands out in front of him with his right hand representing the hot side of the spoon and his left hand representing the cold side (see Figure 1). As he explained how the hot side vibrated and collided, he shook his left hand and brought it closer to his right hand until they were pressed together and shaking simultaneously. Involving the body in the reasoning process seemed to allow Harun to test his own hypothesis about how changes in the speed of vibration of molecules can propagate over a larger area of molecules. He seemed able to think through the implications of his own prior statements by running a physical, body-based simulation through gesture, and it let him to include the specific causal mechanism in his explanation.
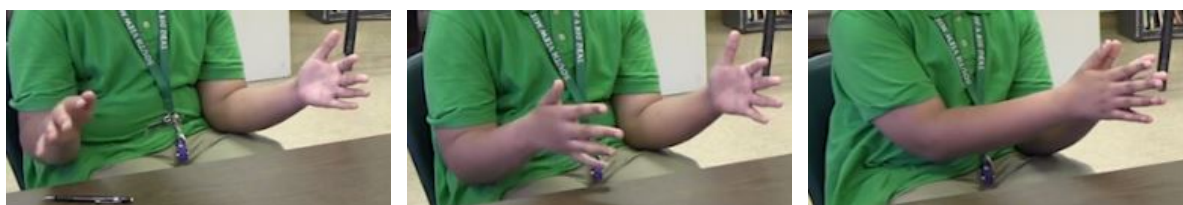
Figure 1. Harun gestures to show vibrating molecules along the length of a spoon.

In our second example, the student appeared to already have the basic causal mechanism of air pressure. Myrna states that the reason that the plunger in a syringe with a closed off end pushes back after it is pressed in, is because the air molecules are "pushing" against the wall of the syringe. However, it is not clear from her initial explanation why the molecules push more when there is less space in the syringe. Later in the interview when she was trying to explain it again, the interviewer used the "show me" prompt, and she says the following:

> **S:** When they have a really big space, and this is the plunger, then they're just occasionally hitting it and then hitting this wall and this wall, and hitting it again. And then when you try to push it in, they're hitting it, like, more often like this. Until they're all just hitting it at once, like that. And then, they're all hitting it and then when you let go now it's like that. Until they're just barely hitting it.

As Myrna is saying this, her hands are flailing all over when she describes the syringe as having a "big space", but her movements are quicker and more compact when it is "pushed in." Unlike her initial explanation, she is conveying that the frequency in which the molecules are hitting the plunger has increased, which strengthens her explanation for why the plunger pushes more when it is compressed.

In our final example, both of Lisa's initial and final explanations of why we have seasons are basically correct. What is interesting, however, is that using gestures changes the perspective that she takes in her

explanation. Initially her explanation is focused on what is happening in a particular place on Earth, but when asked to gesture she takes a more holistic view, representing the Earth in relation to the Sun with her hands (see Figure 2). Here is Lisa's initial explanation, and then the one she gives in response to the "show me" prompt:

S: The way that the Earth is tilted in the summertime where we are gets more direct sunlight even though we get sunlight every day, but the Sun's rays are a…they come from a different angle in the winter so we get the light and heat less intensely.

S: Like so this fist is the Earth and upright is like this, but it's kind of tilted normally so the Sun is always shining like this, but it's flowing out like a spotlight that is stronger in the center and gets the light...it fades more when it gets towards the outer sides of the circle…it goes around the Earth like this and the angle that it's at doesn't change, so if it's here and we're here it would be less intense

Figure 2. Lisa showing the Earth tilted (left) and sunlight shining on the Earth "like a spotlight."

In this case the gesture prompting seemed to switch Lisa's explanation from a "ground" view to a "space" view, which may have different affordances for communication and for solidifying her own understanding.

Conclusion

We have shown in this preliminary study that requesting students to use gestures in the explanations of science phenomena frequently alters the degree to which the student engages with the causal mechanism. Often the gestures seems to lead to more mechanistic explanations, or they change the perspective from which the mechanism is described. These findings suggest that both classrooms and new technologies may find success in improving student explanations through explicit elicitations of gestures.

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The Function of Epistemic Emotions for Complex Reasoning in Mathematics

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Abstract: This study examined how epistemic emotions, motivational mechanisms, and their effects are linked during complex reasoning in mathematics. Data were collected from 80 university students enrolled in mathematics study programs. Participants first answered a series of multiple choice questions regarding knowledge of basic geometry theorems and afterwards solved a complex proof task. Immediately upon task completion, students reported their epistemic emotions as well as motivation during the task. Path analyses revealed that epistemic emotions during problem solving predicted the motivation students invested in solving the complex reasoning task. Finally, intrinsic motivation positively predicted task performance. The findings suggest complex linkages of epistemic emotions with motivational mechanisms during reasoning and knowledge generating processes and demonstrate the adaptive and maladaptive functions of epistemic emotions. Consequently their role for complex reasoning should be considered in future research and can guide instructional design to foster reasoning in mathematics.

Introduction

In mathematics, deductive reasoning is one of the fundamental modes in order to generate evidence for or against a claim or theory, marking mathematics oftentimes as a "cold" science (Sinatra, Broughton, & Lombardi, 2014). However, in order to solve more complex problems and advance scientific discovery in mathematics, reasoning paths have to be refuted, approaches to solutions have to alter between heuristic and analytical strategies, and complex or even contradictory information must be evaluated and at times reconciled. From this perspective, mathematical reasoning is prone to be affected by emotional mechanisms driving epistemic processes (Fischer et al., 2014; Muis et al., 2015). Systematic research examining those links is largely lacking. To address this research deficit, we are investigating the role of epistemic emotions for complex scientific reasoning in the domain of mathematics.

Epistemic emotions have been described to relate to the cognitive quality of tasks and information processing (Pekrun & Stephens, 2012), and consequently their object focus is on knowledge and processes of knowing (Muis et al., 2015). The influence of epistemic emotions on performance and achievement can be theoretically explained by their impact on various variables, including the motivation invested in a learning or problem solving activity (Pekrun, Goetz, Titz, & Perry, 2002; Pekrun & Perry, 2014). The theoretical framework for epistemic emotions proposes that epistemic emotions can positively affect knowledge-generating activities and motivational processes during task engagement. In particular, both positive activating (e.g., curiosity) and negative activating epistemic emotions (e.g., confusion) have been associated with beneficial effects for learning (e.g., D'Mello, Lehman, Pekrun, & Graesser, 2014). By contrast, the negative deactivating emotion boredom has been found to be detrimental (Tze, Daniels, & Klassen, 2015). However, as compared to cognitive effects (Muis et al., 2015) the role of epistemic emotions for motivational mechanisms during complex reasoning has rarely been studied. Consequently, we are investigating if and how epistemic emotions effect complex reasoning in mathematics through motivational mechanisms.

We base our exemplary hypotheses on those few empirical findings which have found positive activating epistemic emotions, such as epistemic curiosity or enjoyment, to consistently motivate exploration (Litman et al., 2005) as well as students engagement (Pekrun et al., 2002) but to also promote intrinsic motivation (Pekrun & Stephens, 2012) during complex reasoning. Boredom, a negative deactivating epistemic emotion, has been associated with task disengagement (Tze, Klassen, & Daniels, 2014; D´Mello & Graesser, 2012) and the lowering of intrinsic motivation (Pekrun et al., 2010) and is therefore expected to reduce the intrinsic motivation to solve the task while it is also expected to have a positive relationship with amotivation. Assuming mediating functions of motivational variables between epistemic emotions and task performance (Pekrun, 2006), we hypothesize that, in turn, intrinsic motivation should be associated with positive outcomes and consequently will positively predict task performance while, for example amotivation, should lead to withdrawal from the task and would consequently have a negative effect on task performance.

Method

Sample
A total of 80 University students from a German University (M_{Age} = 22.91, SD_{Age} = 4.54; 45 male (56.3%), 33 female (41.3%), 2 missing) participated in the study. All students were enrolled in study programs of mathematics ($M_{Semester}$ = 4.28, $SD_{Semester}$ = 3.07).

Materials and measures

Mathematical performance
A geometric proof task was developed based on psychological models of knowledge and deductive reasoning (Ufer, Heinze, Reiss, 2009; 2009a). Here, a geometric stimulus has to be investigated by the participant by applying knowledge of mathematical theorems in order to generate a cohesive proof. A coding scheme was developed and based on two independent raters their concordance was assessed with Cohen's Kappa [k] which ranged from 0.74 to 0.96 [M = .83, SD = .11] indicating overall good reliability. Based on these rated variables the following measures were agglomerated: 1) the number of arguments logically constructed to formulate the proof (based on premises and conclusions); 2) the number of arguments to which a mathematical justification had been added (i.e., a direct reference to a mathematical theory or axiom); 3) the quality of those arguments. As normal distributions were different for each of the three performance measures, z-scores were computed in order to form an overall performance measure for the constructed proof (1).

Prior knowledge
Prior knowledge in Geometry was assessed based on a series of multiple choice questions regarding knowledge of basic geometry theorems before students solved the proof task. One point for each correct answer was given, which resulted in a range of possible scores from 0 to 35 (M = 30.43, SD = 3.72, min. = 15, max. = 35).

Epistemic emotions
Epistemic Emotions that students experienced while solving the complex proof task were measured using the short version of the Epistemic Emotions Scale (EES, Pekrun & Meier, 2011). Each item consisted of a single word describing one emotion (e.g., curious, surprised, confused, anxious, frustrated, excited, bored) and were assessed as intensity ratings (1 = *not at all* to 5 = *very strong*).

Motivational mechanisms
A multidimensional measure of the contextual motivation to perform the task was employed based on the Situational Motivation Scale (SIMS; Guay, Vallerand, & Blanchard, 2000). Each of the following constructs based on four items was assessed: intrinsic motivation, identified motivation, external motivation and amotivation. The intrinsic motivation scale assessed the degree to which a participant reported to having solved the task in order to experience pleasure or satisfaction inherent in the activity (e.g., "Because I think that this activity is interesting"). In contrast, the extrinsic motivation scale measured compliance beyond the activity itself (e.g., "Because it is something that I have to do"). The identified motivation subscale referred to the personal importance or conscious value individuals experienced when they were engaged in the activity (e.g., "Because I am doing it for my own good"). Last, the amotivation scale measured to what extent participants saw no sense of purpose or value in solving the geometry task (e.g., "There may be good reasons to do this activity, but personally I don´t see any"). All self-report scales were adjusted to fit the task specific context of geometry (Instruction: "Why [were] you engaged in this [task]?") and collected via self-report on 5-point Likert Scales (1 = *not at all true of me* to 5 = *very true of me*) so that a higher score on each scale represents a stronger endorsement of the corresponding construct.

Analysis

Preliminary analyses
Pearson product-moment correlations were calculated for all study variables. The epistemic emotions were related in the expected directions, for example, positive activating emotions (curiosity and excitement) were positively correlated while boredom, a negative deactivating emotion, showed a strong negative relationship to curiosity as well as excitement. Further, confusion was substantially related to frustration but both negative activating

epistemic emotions were unrelated to anxiety. Additionally, confusion was negatively related to excitement and surprise.

Curiosity, for example, was systematically related to all motivational variables and showed a strong positive relationship with intrinsic as well as identified motivation while the relationship with external motivation and amotivation was strongly negative. A similarly consistent pattern emerged for boredom. While this deactivating epistemic emotion was negatively related to intrinsic and identified motivation a strong positive relationships was found for amotivation.

Last, only excitement, frustration and boredom were related to task performance. Prior knowledge was significantly related to task performance and consequently included as a covariate in the following analyses.

Path analyses

Path analyses were conducted to test the mediation model. Hayes and Preacher´s (2013) MEDIATE SPSS macro was used with manifest variables to account for small sample size. To test significance, the macro uses bootstrapping (generating a sampling distribution of the effects by pretending the sample is a population and drawing random 10,000 resamples). The Monte Carlo method (Preacher & Selig, 2012) is here applied to estimate paths coefficients. Prior knowledge was included as a covariate for all variables in the model. Mediation analysis tested, while including all variables in one step, whether motivational variables mediated relations between epistemic emotions and task performance.

The analysis included all epistemic emotions as predictors, all motivational variables as mediators, performance as the outcome variable, and prior knowledge as a covariate. The total effects model was significant. Curiosity and excitement positively predicted intrinsic motivation. Identified motivation was positively predicted by curiosity and negatively predicted by boredom. Although the model for predicting extrinsic motivation reached significance only excitement approached significance as a negative predictor. Last, boredom was a positive and curiosity a negative predictor for amotivation during the completion of the task. The model that included task performance as an outcome variable was significant and was positively predicted by intrinsic motivation and prior knowledge.

Lastly, indirect effects revealed that intrinsic motivation experienced during the task mediated the relations between curiosity as well as excitement during problem solving and task performance.

Conclusions and implications

In order to better understand student reasoning and learning during complex reasoning in mathematics, it is crucial to carefully untangle all components underlying and determining student performance. This study examined the role of epistemic emotions experienced during a complex mathematical task in predicting motivational mechanisms and consequently task performance. Results revealed that epistemic emotions predicted different motivational variables during task performance, while in turn, intrinsic motivation positively predicted task performance. Specifically, our findings suggest that positive activating epistemic emotions act as important drivers for perseverance during complex reasoning problems and can profoundly impact the quality and outcomes of cognitive processes (Fischer et al., 2014, Pekrun, 2006). On the other hand, our findings additionally indicate that deactivating emotions may help to explain withdrawal from more complex reasoning tasks. In sum, these complex linkages of epistemic emotions with motivational mechanisms demonstrate the importance for understanding the function of epistemic emotions for reasoning and knowledge generating processes and make their adaptive and maladaptive effects salient. The findings highlight the need to consider epistemic emotions alongside motivational variables when conducting research on reasoning and designing classroom instruction.

Endnotes

(1) All three z-scores were added and then divided by the total number of measures (3) to form an overall indicator of task performance.

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Symposia

FUSE: An Alternative Infrastructure for Empowering Learners in Schools

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Abstract: In this symposium, we examine a unique STEM learning environment that is designed to be interest-driven, learner-centered, and inclusive of many different types of learners. The four papers presented here demonstrate the unique features of the FUSE learning environment that empower learners. Respectively, they describe the ways in which this environment allows learners to engage in diverse *learning arrangements* (Stevens, Satwicz, & McCarthy, 2008), enables them to develop and draw on each other's *relative expertise,* facilitates learner agency, and provides learners with a toolkit of knowledge and practices to use in other STEM learning contexts.

Keywords: informal learning, self-directed learning, agency, relative expertise, situated learning

Session summary

The typical organization of classroom activities is familiar to us all; a teacher manages a cohort of children working on a curriculum prescribed by educational authorities; the children's work is tested and graded by the teacher and each child is attached with a record assembled from these grades. Within this organization, children's interests are usually minimally involved, and students have little control of what they do, when, with whom, and how it is evaluated. Furthermore, this typical classroom structure has been argued by many as recalcitrant to true reform or reorganization (Sarason, 1996; Tyack & Tobin, 1994), despite compelling arguments that this particular organization does not lead to learning or at least not to children learning what is intended (Becker, 1972). Other lines of research have documented how difficult it is to change teacher practices and beliefs about student active and self-regulated learning (Meirink, Meijer, Verloop, & Bergen, 2009), and how much work is required to create and support alternative learning environments (Blumenfeld et. al, 1991; Kirschner, Sweller, & Clark, 2006).

In this symposium, we present a multi-faceted portrait of FUSE, an *alternative infrastructure for learning* (Stevens, 2007). The design inspiration for FUSE draws largely on research documenting the effective social and material conditions often found in *out of school* learning environments (Cole 2006; Stevens, Satwicz, & McCarthy, 2008; Bransford et al, 2006). Previous analyses (Jona, Penney & Stevens, 2015) demonstrate that many of the undesirable features of typical classroom activities are largely absent from FUSE Studios (i.e. classrooms in which FUSE is implemented). For example, FUSE Studios are centered around two dozen challenge sequences that 'level up' like video games. Participating students can choose what challenges they want to work on and if and when they will continue with particular challenges, based on their own interests. They can choose to work alone or with peers. They are not graded or assessed formally by adults; instead, using photos, video, or other digital artifacts, they document completion of a challenge to unlock the next challenge in a sequence.

This symposium offers several lines of analysis that document how FUSE is an alternative infrastructure for learning, tied to the ICLS theme of empowering learners. The four papers present brief empirical case studies constructed from ethnographic field data to demonstrate key learning phenomena in FUSE Studios embedded in school environments. All of the papers draw on a shared data corpus collected between 2013-16. The corpus includes ethnographic observations, informal conversations, and whole room and point-of-view video recordings from fifth and sixth grade classrooms offering FUSE for 90 minutes each week (and from selected other STEM-related courses in those schools). The corpus also includes data collected through the FUSE website cataloguing student challenge activity and providing an aggregated picture of student activity across the more than 50 FUSE Studios currently active. The first paper documents key differences between FUSE classrooms and traditional classrooms as learning environments. The second paper documents that students in FUSE develop *relative expertise*—that is, students develop expertise relative to each other through individual patterns of participation in challenges—and come to recognize and rely on the expertise of their peers. The third paper highlights instances

of student agency, evidenced by students' spontaneous and creative extensions of FUSE activities. The fourth paper explores the ways learning in FUSE impacts learning in other school contexts. Taken together, these four papers show that the implementation of FUSE is realizing a truly alternative infrastructure for learning in schools, facilitating empowering learning arrangements that are quite atypical of school. This 90-minute symposium will begin with a ten-minute introduction to FUSE. Each paper will be presented for twelve minutes. Our discussant will conclude with a twelve-minute synthesis. Twenty minutes will be devoted to questions from the audience.

Learner choice and the emergence of diverse learning arrangements in FUSE

Lauren Penney, Kemi Jona, and Reed Stevens

This paper explores how FUSE Studios are organized, describing key design elements, the ways these differ from a traditional classroom model, and the types of diverse learning arrangements that emerge. Data in this paper was primarily collected from five classrooms in the 2013-14 school year and the analysis was refined through discussions within the research team about ongoing data collection during the 2014-15 (one classroom) and 2015-16 (seven classrooms) school years.

Learner choice in FUSE leads to the emergence of diverse and productive learning arrangements. Choice, as is the norm in informal learning environments but rare in formal education, is fundamental to the FUSE experience in multiple ways. First, youth participants choose among the current (but growing) library of challenge sequences, based on their own interests. They also may choose to leave a sequence or a challenge at any time. Participants can also choose to work alone or with peers (see Figure 1). And in general, while youth participants are given many resources, tips, and guidelines for completing challenges, ultimately they may choose any course of action as a route to challenge completion. Supporting learner choice in these ways relies on a set of challenge sequences that have been carefully structured to invite initial participation and a website that supports students through successive challenge levels that increase in complexity. The challenge completion process also increased learner choice; rather than the teacher assessing and approving progression, students self-document their challenge completion using pictures or video to unlock next challenges in a sequence. This process frees students to pursue their own interests on their own time frame.
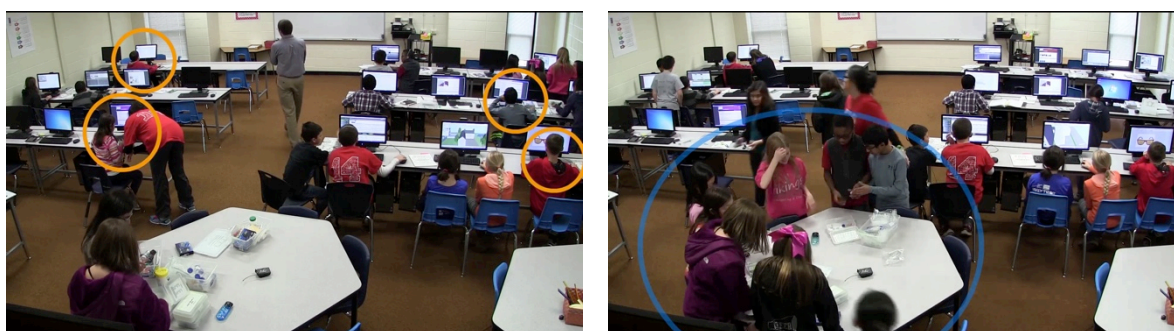
Figure 1. Frames from a video showing diverse learning arrangements in a FUSE Studio, including individual (left) and group arrangements. Both images include numerous student pairs.

In general, the organization of activity in FUSE Studios is a fairly complete inversion of the typical organization of activity in traditional classrooms and thus represents a partial 'alternative infrastructure for learning' (Stevens, 2006). In these typical classrooms, a teacher manages a cohort of children working through the same activities at the same pace from curricular materials designed by corporations and distant educational authorities. Teachers typically instruct from the front of the room, and they tend to be the nearly exclusive source of authoritative knowledge in classrooms. They also define and regulate acceptable activity structures (i.e., group work, whole class discussion, etc.), thus shaping student opportunities for collaborations and conversations (Lemke, 1990). Within this familiar organization of activity, children's interests are minimally involved. And choice is virtually non-existent; students have little control of what they do, when, with whom, and how and when it is evaluated.

In FUSE, students' freedom to choose what to work on and with whom enabled a diverse set of student-initiated learning arrangements, arrangements that were dynamically and fluidly formed, dissolved, and reformed. Figure 2 provides a snapshot of four students' challenge choices across an entire school year. Each dot in this figure represents a challenge level attempt, different challenge sequences are represented through color, and levels are represented by dot size with larger dots representing higher and thus more advanced challenge levels. This

data shows that Shruti and Sanika had similar challenge activity (the colors mostly match). During their work on the Jewelry challenge sequence (purple) and the Selfie Sticker sequence (dark green), these two girls sat next to each other and used their own computers and materials to complete the challenges together. This parallel collaboration allowed the girls to access each other as thought partners but did not tie them to working on the same exact artifact. In contrast, Rakesh alternated between many different challenge sequences, often working on multiple challenges in the same day (e.g., the multi-colored dots seen between November and December). He and another student, Vihaan, used the same computer and materials when collaborating to create a 3D model of a car, working to create a joint final product that they 3D printed twice (once for each of them). Finally, Mario's activity also contrasts with the others. He worked on a few different challenge sequences with another student, Dan, before starting Electric Apparel (pink), which he pursued independently and exclusively for the last half of the school year. These and other examples emerged throughout the year, illustrating the fluid and flexible ways students arranged collaborative activity to suit their preferences and needs.
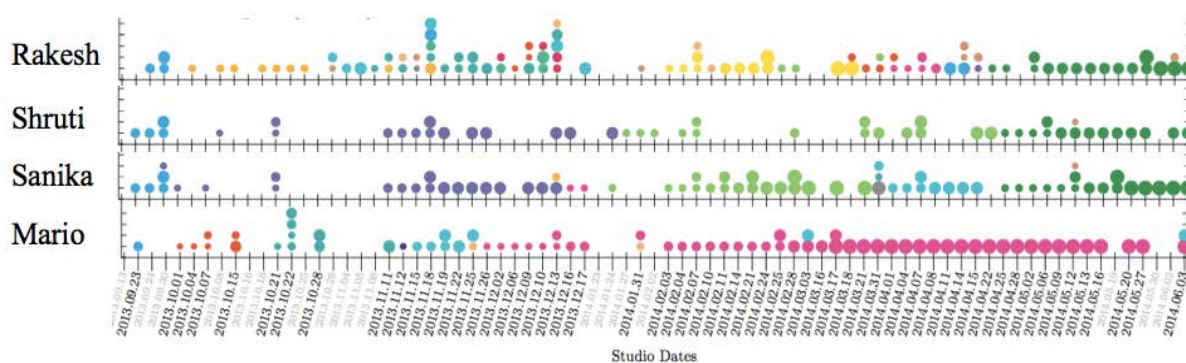
Figure 2. Patterns of challenge activity from four 6th graders during the 2013-14 school year.

Taken together, these examples demonstrate some of the rich diversity of collaborative learning arrangements that emerge from empowering learner choice in FUSE. Two critical design elements of FUSE that foster these collaborative arrangements are: 1) a set of challenge sequences that have been carefully structured to introduce novices to new ideas and support them through more complex iterations of those ideas, and 2) giving students the freedom to choose what to work on, when, and with whom. Removing traditional classroom structures and routines did not result in chaos as many educators often fear. Rather, as students gained experience with FUSE challenges and took responsibility for their own learning, they were learning how to be self-directed, productive, and independent workers. They set their own pace and worked towards goals they chose for themselves. They were learning how to teach, learn, and coordinate work with minimal adult guidance; the very skills Casner-Lotto & Barrington (2006) and others lament are missing from the traditional organization of schooling.

Developing and recognizing relative expertise in FUSE

Dionne Champion, Lauren Penney, and Reed Stevens

Traditional methods of STEM education position the child as a novice and create narrow opportunities for children to demonstrate and constructively utilize their developing skills, related interests and capabilities, perhaps even inadvertently suppressing them (Stevens, 2000; Bevan, Bell, Stevens, & Razfar, 2012; Barron, 2006). Researchers have explored expertise in terms of domain mastery (Ericsson, Krampe, & Tesch-Romer, 1993), developed models for how novices become domain experts (Alexander, 2003), and discussed pathways along which students move in developing science expertise (Schwarz et al., 2009; Alonzo & Gotwals, 2012). Yet we have a limited understanding of young people's developing STEM expertise in real time and know little about how young people *recognize* and *utilize* the expertise of their peers along these pathways towards expertise (Bricker et al., 2008). This paper examines activity in FUSE Studios to expand our understanding of the development and recognition of what we call *relative expertise*, how young people's growing relative expertise becomes valued by teacher and peers, and how relative expertise leads to fluid and varied formulations of peer collaboration, sharing, and assistance. Data used in this analysis comes from two school years (2013-15).

By empowering students with choice about the challenges they want to work on and when they want to move on to something else, FUSE allows differentiated knowledge among participants to accumulate and circulate for many challenges at once, a stark contrast to the lockstep pacing of typical school curricula. This creates an

environment of shareable knowledge resources, as different students become knowledgeable with the tools and technologies associated with different challenges at different times and then share that knowledge with one another. Students develop *relative expertise* as they become more knowledgeable than their peers in a variety of challenge-related skills including, for example, connecting LED lights in a parallel circuit, designing CAD files in Tinkercad, or using tools like a vinyl cutter and 3D printer. The following examples show how Anika and Melissa each developed relative expertise based on their different participation trajectories.

Anika, a sixth grader, developed specialized expertise with the 3D printer, and became the resident 3D printing expert in her classroom. After completing a 3D printing challenge, she decided to spend her time in her FUSE classroom helping others troubleshoot their 3D printing issues. She spent months helping her peers in a variety of ways, including helping to prepare their CAD files for printing, troubleshooting and fixing the 3D printer when it malfunctioned, and keeping track of the class 3D printer "queue." Anika even became a recognized resource for adults, giving 3D printing tutorials to teachers and support staff in the building. We see similar patterns of expertise development across multiple students in FUSE. All students become relatively good at something, developing different but overlapping skills. The FUSE activity system allows participants to develop STEM competence by providing a space where they can showcase their newly developing skills in ways that are less "schoolified". Since "not knowing" is not viewed negatively and there is little fear of judgment and no grading in the FUSE classrooms, students are willing to fumble through things on their own or ask for help to develop their competence. Also, there is no disincentive to help others, so students who figure out how to fix or troubleshoot their own issues often offer their help to other students, which reinforces their own developing skills and validates their relative expertise. Students are often publicly recognized as relative experts by classmates or teacher-facilitators who go to them for help or identify them as resources for others.

In this setting of diverse relative expertise, students also learned how to recognize and evaluate the relative expertise of others, learning who to seek out for specific types of help (Hertzog, 2002; VanderBorght & Jaswal, 2009). For example, Melissa gravitated to the Selfie Sticker challenge sequence (creating a graphic design that can be output on a vinyl cutter to create multi-layered stickers) and worked hard to develop relative expertise in that sequence, troubleshooting issues on her own and then answering questions from classmates. When Paulo and Kyree both expressed difficulty starting this challenge, Melissa first assured Kyree "it's not hard, I got it already" and then, after he adamantly refused to believe her, she walked over and helped him through the initial steps of downloading a required graphics template and opening it in the appropriate software program to begin editing it. After this exchange, other students in the vicinity sought her help with this challenge. Later Kyree attempted to help his friends, but eventually requested, "Melissa, come help these girls," reaffirming her relative expertise. Kyree recognized the value of Melissa's contribution to his own progress and positioned her a resource for classmates. As she developed relative expertise on this challenge and others, she freely provided help when requested, even proactively offering tips and pointers to others as she moved throughout the room.

These examples illustrate how FUSE provides students opportunities to collaborate with and value their peers in ways that enable distributed expertise to develop. Unlike traditional school, every student in a FUSE classroom chooses their own path through the challenge sequences, developing a diversity of experiences with various challenges, materials, and tools, and thus developed different sets and varying levels of relative expertise. As they progressed, students began to look to one another as reliable resources, creating an environment in which they could become recognized by peers and facilitators as relative experts. These types of interactions in which peers relied upon one another for their knowledge have been shown to increase self-esteem (Aronson & Patnoe, 1977/2011) and are important for developing a positive identity about subject matter (Cribbs, Hazari, Sonnert, & Sadler, 2015). Our analysis shows that when we design environments that give children the opportunity to develop and share expertise, they often take up that mantle and become empowered learners.

Productive deviations as manifestations of student agency in FUSE

Jaakko Hilppö, Reed Stevens, Kemi Jona, Ruben Echevarria, and Lauren Penney

This paper focuses on exploring three interrelated questions: a) How, and in what kind of situations, do students employ their agency to create new learning opportunities for themselves?; b) What kind of learning situations are thus created?; and c) How are these new learning opportunities play out over time? In answering these questions, we seek to understand the complex interplay between student agency and different kinds of designed learning environments like FUSE.

According to many learning sciences perspectives, one of the fundamental challenges for any educational endeavour is to organize environments which spark and promote the agency of the learners themselves. Participatory learning structures provide the students "the opportunity to decide what they wanted to investigate relative to the presented unit of study, and how they would conduct their investigations" (Siri et al., in press, p.

4). Recent studies focusing on student agency in participatory learning structures embedded within formal instruction suggest how supporting student agency can lead to meaningful engagement among the learners themselves. However, we still lack for accounts of how students pursue their own STEM-focused interests within these environments and take agentive advantage of the learning opportunities offered within them. Understanding the qualities of these opportunities and how they emerge not only adds to the existing learning sciences literature regarding agency in learning, but also paves the way for an accounting of how various participatory learning structures can invite learners to pursue and enrich their own interests.

FUSE provides a rich setting to explore the emergence and qualities of student-created learning opportunities and their development for at least two reasons. The first is student choice as a core design feature. That is, in contrast to conventional classrooms, students in FUSE can pursue and shift between challenges as they wish. Second, FUSE challenges afford multiple solutions and thus provide students with latitude in their how they work. These, and other elements of FUSE studios reflect El'konin's and Vygotsky's (2001) notion of *productive incompleteness* as a precondition for the expression of student agency.

Eteläpelto et al. (2013) and others have noted the complexity of defining agency for empirical analysis. In this study, echoing Rajala and Sannino (2015), we focus on student agency as *productive deviations* that build on, but also depart from the intended FUSE challenge structure. These deviations, when pursued and further developed by the students, represent locally new learning opportunities, originally unintended by FUSE designers in their specific form but anticipated by the general pedagogical design philosophy of FUSE.

We employed iterative interaction analysis methods (e.g., Erickson, 2006) to uncover potential manifestations of student agency in FUSE from a larger ethnographic data corpus of FUSE Studio implementations during 2013-2015. Our analysis has thus far revealed several potential telling cases (Mitchell, 1984) of productive deviations among students in FUSE studios. Below are two vignettes of productive deviations where students build on a particular FUSE challenge, but also depart significantly from the intended challenge design to pursue their own interests.

Example 1: Anna and Leena are working on the third level of the Laser Defender challenge, which involves bouncing a laser light beam through a maze of mirrors. While arranging the needed mirrors Anna and Leena talk with a second pair engaged in the same challenge at the other side of a big round table. The pairs are talking when suddenly the laser of the other pair hits Anna's and Leena's mirrors. A lively discussion ensues regarding how the laser challenge could be made even harder (and in their words thus "cooler" and "more fun"), by asking them to collaborate with another pair or by putting a timer on the challenge. After a short while, the conversation tapers off as both pairs focus on working on their own challenges.

Example 2: While working on Solar Roller, a solar-powered car challenge, a group of five boys approached one of the observing researchers to inquire how they could buy the challenge material for themselves. The students' desire for their own set of materials was driven by the popularity of the challenge and the requirement that each group had to dismantle their car after they had worked on it. This significantly hampered the students' efforts to complete the challenge as they had to rebuild the car each class period. The researcher explained how the students could order the materials and a few weeks later the students brought their own material to the studio. However, rather than just engaging with the existing challenge structure, the students also created their own challenges and experimented with the car in different settings outside the FUSE Studio. *"Now that we actually bought it [the solar roller kit], we actually have the freedom to do whatever we want with it",* Arjun, one of the boys in the group, explained.

Both vignettes show how students in FUSE studios engage with the challenges in ways which expand on the original challenge structure. In the first vignette, the students' actions are inspired by a serendipitous event which incites them to jointly imagine new and harder challenges, quite atypical agency for students in a classroom. In the second vignette, scarce access to the materials leads the students to purchase a car kit of their own and to further explore what they can make and do with the parts. Importantly, the second example seems to represent an even greater degree of agency. That is, not only did the students envision extending the activities, they actually realized this extension. This preliminary analysis suggests that the concept of productive deviations can help us look for how and when learning environments can foster more empowering (i.e. agency realizing) STEM learning experiences.

You *can* take it with you: Empowering learners across contexts
Kay E. Ramey

A central way in which FUSE provides powerful learning affordances is by breaking down the silos of A key way in which FUSE provides powerful learning affordances is by breaking down the silos of traditional STEM disciplines, and engaging learners in more authentic, interdisciplinary, and personally meaningful experimentation

and making (e.g., Dewey, 1897; Resnick et al., 2009). Consequently, FUSE activities have the potential to not only motivate students to engage in future STEM learning, but also to provide them with a toolkit of knowledge and practices to use in future STEM learning endeavors (e.g., Vossoughi & Bevan, 2014). However, to understand whether or how students take knowledge and practices learned in FUSE and apply them in other STEM learning contexts, we must follow students as they traverse these boundaries across contexts. The goal of this study was to do just that, focusing on three specific questions: (1) What practices are learned in FUSE; (2) How do learners use these practices in other STEM learning contexts; (3) How is thinking and learning in both FUSE and other STEM contexts contingent upon the sociomaterial conditions of the respective contexts (e.g. Cole, 1996)?

To answer these questions, I observed seven classes of fifth and sixth grade students over two school years, during both FUSE (90 minutes per week) and math and science class activities, identified by teachers or students as related to FUSE. The data presented here are from one class of fifth grade students participating in both FUSE and a tetrahedron kite-making activity in their math class (one hour a day for four days). This kite activity occurred at the end of the school year, after learners had participated in FUSE for a full year. Drawing on cognitive ethnographic methods (Hutchins, 1995), my findings are based on both ethnographic observations of classroom activity and micro-analysis of whole room and point-of-view video, captured by seven focal participants who wore 'visor cams'.

I observed learners engaging in many of the same collaboration, inquiry, and spatial and design thinking practices in both the FUSE classroom and in the math classroom during the kite activity. In particular, over the course of the four day kite activity, both teacher and students made moves that transitioned the activity system from a traditional math class activity system (beginning of Day 1) – characterized by students sitting in their seats, working individually, and asking the teacher for help – to a FUSE-like activity system (end of Day 1-Day 4)— characterized by learners getting up and moving around, helping each other with questions, and engaging in self-directed research and experimentation.

The teacher's experience as a FUSE facilitator influenced her instruction during the kite activity, and consequently her students' ability to engage productively with the activity. For example, during the kite activity, she said she planned to (and did) take a relatively hands-off approach to instruction, more typical of her behavior during FUSE than during regular math class. Rather than directly answering students' questions, she encouraged them to consult the directions or to do independent research on laptops. As a result, when students got stuck, they studied the instructions, asked each other to share expertise, did independent research (regarding tail and string placement), or engaged in self-directed testing and design iteration. On Day 4 of the kite activity, as students raced back and forth between kite test-flights and an outdoor "maintenance station" where they iterated on their kite designs, the teacher commented on how much more "independent" and "collaborative" the students were than those in past years (who had not had FUSE). Pointing to students modifying their kites at the maintenance station, she noted, "[They're] helping each other and problem solving, and they're not giving up as easy."

The shared characteristics of FUSE challenge work and the kite activity also led students to make their own connections between the activities. For example, during the kite activity, one learner, Aarav, mentioned that making 3D pyramids for his tetrahedron kite was like making pyramids in a CAD program (Sketchup) during FUSE. This prompted other students, who didn't see this connection to disagree, citing differences between physical and computer-based models. Importantly, during FUSE, Aarav frequently did the Dream Home challenge (a CAD challenge done in Sketchup) and professed interest and expertise in that challenge. He regularly offered other students advice on that challenge, and at one point said, "I only do Dream Home." It makes sense then that he would see connections between these two activities that other students, who primarily did other FUSE challenges, might not.

Aarav also engaged in at least two productive problem-solving practices during both FUSE and the kite activity. The first, an embodied, spatial practice that Aarav (and many of his classmates) engaged in, was *epistemic object manipulation* (Kirsch & Maglio, 1994). While working on Dream Home, Aarav frequently used the rotate tool in Sketchup to turn his house and view it from different angles. During the kite activity, he also manually rotated his kite, looking at it from different angles, to decide where to attach his string and tail (See Figure 3). The second practice Aarav and his classmates engaged in was sharing expertise. For example, during FUSE, Aarav would frequently ask advice of or offer advice to other students working on Dream Home. During the kite activity, he also engaged in this practice, asking another student for help with a difficult aspect of kite construction (connecting 2D triangles to form a 3D pyramid), and then, later, offering similar help to other students.
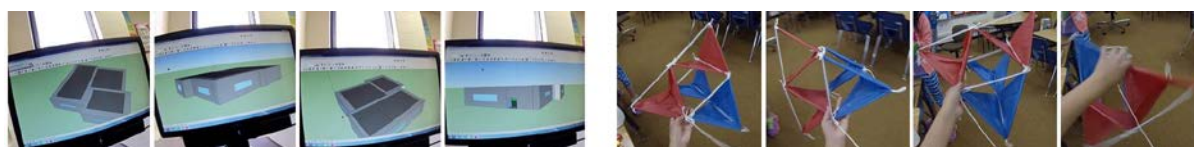
Aarav and his classmates provide examples that, through participation in FUSE, students are learning STEM problem-solving practices in flexible ways that allow for their productive use in other contexts. However, as in any case of "transfer," certain things need to be true for learners to move practices between contexts. First, there must be similarities in the sociomaterial conditions of the two activity systems (i.e. opportunities for collaboration; Tuomi-Gröhn & Engeström, 2003). Second, learners must recognize the connections between the two activities themselves (i.e., Aarav seeing connections between Dream Home and the kite activity; e.g., Lobato, 2012). These insights further our understanding of the impact of FUSE on students' STEM learning in other contexts and provide guidelines for educators hoping to aid students in bringing knowledge and practices from FUSE or other informal making and design contexts into STEM classrooms.

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Acknowledgements

Qualitative Analysis of Video Data: Standards and Heuristics

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Abstract: Video research is an increasingly important method in the learning sciences. Video provides unique analytical affordances to researchers but also presents unique tensions, many of which have not yet been adequately addressed in the literature. The authors of this symposium draw on their diverse experiences, analyzing a variety of video corpuses, to provide theoretical and methodological standards and heuristics for the process of video analysis. We focus on three themes central to the process of video analysis that would benefit from increased theoretical and methodological attention: transcription tensions, defining the unit of analysis, and representing context. We discuss how our approaches to video analysis are framed by theory and how we have applied them to specific datasets, to answer a variety of research questions. In doing so, we make explicit some crosscutting methodological norms and invite continued discussion about these norms from multiple analytic traditions.

Keywords: video, qualitative, methods, analysis, data representation

Session summary

Researchers increasingly rely on video records to analyze the processes of teaching and learning. Video provides both breadth (footage that spans weeks or months of activity) and depth (a richly detailed, moment-to-moment interactional record). Video creates powerful new affordances, such as the ability to rewind or to see multiple participant perspectives concurrently, that traditional qualitative research methods (e.g., Glaser & Strauss, 1967; Miles & Huberman, 1994) generally do not afford. The literature on using video in the study of teaching and learning provides guidance for researchers in selecting, capturing, and representing video data (see Derry, et al., 2010, for a recent review). In particular, there are rich commentaries on approaches to progressively refining hypotheses (Engle, Conant & Greeno, 2007), conceptualizing the epistemology of video representations (Goldman, 2007), and representing video data in ethnographically adequate ways (e.g., McDermott, Gospodinoff, & Aron, 1978; Ochs, 1979). However, the field lacks consensus on theoretical and practical guidelines for the *process* of video analysis: asking the difficult, multilayered questions of "what do I do with all of this video?" and "how do I go about doing it?" In this symposium, we integrate guidelines from specific analytic traditions (e.g., interaction analysis) and general methodological approaches to qualitative data analysis (e.g., Miles, Huberman & Saldana, 2014). We discuss the reflexive relationship between various learning theories, existing methodologies, and the methods that we have developed to address the unique affordances and challenges of analyzing video data.

Each of the authors draws on experience working with a different corpus of video data. Our research interests are wide-ranging and include middle-school science instruction, museum interactions, at-home family inquiry, teacher practices, spatial thinking, design of learning spaces, and learning through dance. Across these different data sets and research questions, however, we have recognized a common set of core challenges in video data analysis that are not adequately addressed by current literature on video methods. Through workshop collaborations, we have identified issues of practical and theoretical concern for our video research, and we have developed a set of standards and heuristics to work through these challenges that cut across different research projects and analytic traditions. Our findings, and this symposium, are organized into three areas of focus:

1. *Transcription tensions*. Which interactional phenomena need to be transcribed? When? How? We consider these questions in the context of our work, characterizing transcription as an analytic and interpretive act, central to ongoing analysis, and propose a recursive method of video transcription.

We also show how transcription can be used as a tool in the analytic process and demonstrate a technique for foregrounding visual phenomena during analysis.

2. *Defining the unit of analysis*. The richness of video data often results in multiple rounds of analysis that include revisions to theoretical frameworks. It can also lead to separate lines of analysis using distinct theoretical frameworks. Even given the same video data, changes in frameworks can lead to changes in codes AND in the units being coded (e.g., individual utterances; episodes of talk + gesture). We discuss strategies for maintaining flexibility and issues in reporting reliability with these kinds of analyses.

3. *Representing context*. Video data afford unique access to context surrounding phenomena of interest, but there is little guidance on how to incorporate this context into analysis. We explore different ways that context can be represented and analyzed using video data, as constituted both by the researcher and by participants.

These three areas of focus are not novel; in fact, they are some of the first issues with which novice qualitative researchers will grapple. However, video data provide new possibilities for how to address each issue. Although norms for utilizing these new possibilities exist in practice within various analytic sub-communities, they are not explicit or available to the broader research community except as individual case studies exemplifying particular approaches. For example, Engle, Conant, & Greeno (2007) discuss the general strategy of progressively refining hypotheses. They also provide a specific example of how they transcribe, select units of analysis, and represent context. However, that example does not provide general guidance for *how* to make or evaluate those decisions throughout the analytic process. Our goal in this symposium is to make these decision-making norms explicit as general strategies and heuristics. Much like how proposing theoretical mechanisms for scientific phenomena then allows for empirical investigation of those phenomena (Machamer, Darden, & Craver, 2000), proposing theoretically-grounded strategies and heuristics for video analysis allows for refinement, revision, or rejection of these strategies. We view this as a critical process for the field for continued development of methodological rigor around analysis of video data.

We will structure this symposium as an interactive session. We will begin with a 5-minute introduction to the affordances, tensions, and open questions in video analysis. This will be followed by 10-minute presentations by the authors of each sub-section, covering their theoretical and methodological standards and heuristics by situating them within concrete examples from their data corpuses. Following the presentations, the discussant will present questions for discussion. These will guide interaction at distributed stations during the next 50 minutes, where the authors will present more detail about how they have applied these standards and heuristics to their specific analytic contexts and invite feedback and discussion from session participants. We will conclude with brief summary remarks from the discussant and time for whole-group discussion.

Transcription tensions
Danielle Keifert, Exploratorium; Kay E. Ramey, Peter Meyerhoff, and Christina Krist, Northwestern University

Video uncovers a wide range of interactional modalities; people use talk, gesture, gaze, body position, facial expression, movement, and material objects to exchange ideas and information (Goodwin, 2013; Hall, 1999). How can the complexity and dynamism of knowledge in use (Hall & Stevens, 2016) be captured in static representations, and how does creating those representations shape our understanding of interactions? Researchers have long understood that depictions of action through transcription are theoretical in nature (Ochs, 1979); transcription decisions can be political (Bucholtz, 2000) and position research within a particular tradition (Bezemer & Mavers, 2011). To create a transcript is to make consequential choices about which phenomena merit representation. This relies upon our understanding of what is happening in the interactions we represent. The decision to transcribe in a particular style cues a specific lens on what happens in activity; transcribing words exclusively, for example, obscures all other interactional phenomena. The transcript is not a neutral piece of objective data but rather the product of an analytic move, in which the researcher selects one or more interactional modalities to focus on in the analytic process (Bezemer & Mavers, 2011). Goodwin (2003) recognized "recursive interplay between analysis and methods of description" (p. 161), as the researcher views, re-views, and documents video-recorded activity through multiple lenses, to progressively explore and develop an argument. Different, equally valid, transcripts can be produced from the same video record, reflecting differences in research questions, analytic frames, and phenomena of interest. Transcripts evolve as researchers work to develop arguments, and the process of working through multiple lenses can support more systematic analysis of the multiple modalities of knowledge use. Creating multiple transcripts during the analytical *process*, regardless of the final transcript *product*, supports researchers' developing understandings of interaction. Here, we build on Goodwin's idea of

recursion to demonstrate a method of *recursive transcription,* a theoretically-grounded heuristic for exploring knowledge in use.

Recursive transcription

Video offers an open invitation to the researcher to look beyond the spoken word and find meaning from other dimensions of participant activity. Researchers recommend being sensitive to and intentional about which semiotic fields are chosen for transcription (Bucholtz, 2000; Derry et al., 2010; Goodwin, 2013), though researchers mostly focus on such representations in final products (e.g., articles, presentations). We propose that the development of detailed transcripts representing multiple semiotic fields is more than a matter of representational choice in final product: it can guide the process of noticing during analysis. By engaging in *systematic,* sequential analysis of verbal and nonverbal interactional phenomena, the researcher must consider the possibility of meaning in modalities other than talk. Drawing on Stevens (2012), Hall (1999), and Goodwin (2013), we identify these nonverbal, semiotic fields of interest as: gesture and pointing, gaze and attention, body position and movement, touch, tone and inflection, facial expression, and engagement with material objects.

For example, in a study by Keifert (2015), she selected a moment for close analysis in which toddler Catherine asked Dad about a thermometer. In a first transcription pass, she documented content of talk as "Dad: See the red in there. The red line? If the red is, if the red line goes up here in this red area it's hot." She then reviewed the video repeatedly, attending on each pass to a different modality represented above. This "building-up" process produced a detailed multimodal transcript in narrative form (see partial transcript below). Critically, this process encouraged Keifert to notice interactional phenomena other than talk. For instance, in documenting that Catherine turned away as her brother splashed nearby, then quickly turned back to look at Dad's gesture (see below "[6]here in this red area"), the researcher was positioned to notice Catherine's sustained interest (looking again after her brother quit splashing) although Catherine did not express interest verbally. Through considering and transcribing a broad range of modalities in her analysis, Keifert determined that the following indications of talk, gaze, touch, gesture, and engagement with objects merited inclusion in the final transcript:

> Dad: [1]See the [2]red in there. [3]The red line? [4]If the red is, [5]if the red line goes up in [6]here in this red area it's hot.
> [1] *Catherine looks at the thermometer as Dad touches the thermometer.*
> [2] *Dad uses his finger to point to the red line in the middle of the thermometer.*
> [3] *Dad runs his finger up the middle of the thermometer from top to bottom.*
> [4] *Catherine turns her head away from her brother splashing.*
> [5] *Splashing stops and Catherine turns back towards Dad and the thermometer.*
> [6] *Dad points and makes a small circle pointing to the top of the thermometer.*

An alternate move would have been to focus on the thermometer as a scientific artifact, for example representing the number scale to which the participants oriented their understanding of temperature.

Having decided *what* to transcribe, the decision turns to *how*. Jefferson's (2004) conventions for transcribing talk are widely accepted in the field of conversation analysis, but a range of techniques have been proposed to address the challenges of multimodal transcription (Jewitt, 2009; Bezemer & Mavers, 2011). During the transcription process, it may be sufficient to translate nonverbal activities into narrative verbal descriptions (as above). However, for some interactional data and analytic frames, an alternative approach is needed, which circumvents the translation errors inherent in re-representing visuospatial modalities (e.g., gesture) in words. We refer to this approach as *visual transcription.*

Visual transcription

Figure 1 illustrates three ways of representing the moment Dad oriented Catherine to the red line in a visual transcript. When representing interactions, communicating action and spatial relations is a key challenge. Each of these representations foregrounds a different aspect of activity: the still provides a detailed visual inventory of people, objects, and space within the camera's frame; the sketch focuses on body positioning and action (e.g., removing the squirt gun in Dad's left hand, adding arrows indicating Dad's motion); the verbal transcript reports spoken words. Keifert created multiple visual transcripts, in addition to these, to explore this one moment during analysis, but ultimately decided on a combination of 1B and 1C to support the claim that Dad made "hot" and "cold" relevant extremes when talking about temperature. This process of recursive visual transcription supported her identification of all elements of the interaction—verbal (e.g., Dad's words) and nonverbal (e.g., Catherine, Dad, thermometer, gaze, body positions, and gestures)—allowing her to identify and edit out distractors (e.g.,

gun, pool, brother). Such streamlining allowed her, and her audience to focus on features of the interaction made relevant by participants and related to her argument. Thus, visual transcripts foreground analytical decisions that might otherwise be left implicit, and serve as documentation of those decisions.

| 1A | 1B | 1C |

Dad: If the red is, if the red line…

Figure 1. Representations of video data as a video still (1A), a sketch (1B), and a verbal transcript (1C).

This example highlights a particular limitation of video transcription: the challenge of representing gesture. Whereas researchers working with talk can draw on a rich representational scheme from linguistics and conversation analysis (Jefferson, 2004), there are few such *explicit* standards for depicting gesture. We encourage further work to develop explicit transcription techniques—*in process,* to guide analysis, and *in product,* to guide readers—to capture gesture as systematically as verbal communication.

Lessons learned

Though the above examples focused on one moment of interaction, the authors here study diverse phenomena in diverse contexts. Each of us has approached the complexity of transcription in our own way, but the process of recursive, visual transcription has led us all to new insights similar to the examples above. We believe that our experiences with transcriptions of multiple semiotic fields provide the following insights for the field: (1) that the "what, when, and how" of transcription can and should remain in flux as we develop our arguments, because (2) it is precisely through engaging with these decisions that we come to understand our data more clearly. In a field lacking in both consensus and detailed, process-based guidelines for transcribing and analyzing video data, we encourage recursive, visual transcription as an integrative standard for diverse methodological approaches.

Defining the unit of analysis

Christina Krist, Krystal Villanosa, and Kay E. Ramey, Northwestern University

Scholars using video data maintain that how researchers approach video analysis depends on their theoretical commitments and the specific research questions they are pursuing (Barron & Engle, 2007; Goldman, Erickson, Lemke, & Derry, 2007). We add that the richness and complexity of video data often results in iterative cycles of analysis that include revisions to theoretical frameworks. It can also lead to concurrent or asynchronous analyses that employ distinct theoretical frameworks. In both cases, changes in frameworks lead to changes in how we define our unit(s) of analysis—meaning we make changes not just to our codes, but to *what* we code. These changes have deep implications for how we determine reliability and think about representativeness. Here, we discuss how theoretical frameworks determine what phenomena are analyzed, how they are analyzed, and how we might re-think reliability. We place particular emphasis on the fluidity of unit(s) during iterative cycles of analysis, highlighting both the practical and theoretical challenges we encounter in our work.

To ground our discussion of how theoretical frameworks shape our interpretation of video data, particularly how we define our unit(s) of analysis, we first detail data collected from a study conducted in a museum. These data consist of two sets of video recordings. The first set is of parent-child dyads playing an interactive game. The second is of parent-child dyads discussing objects in two exhibit cases. These data were collected to understand the effect of games on museum visitors' conversations around exhibited objects. The two theoretical frameworks we applied to these data were conversational elaboration (CE; Leinhardt & Crowley, 1998), and cultural forms (Saxe, 1999). CE is defined as visitor talk taking place during a museum visit and focuses on how meaning, experiences, and interpretations develop. Cultural forms originates from Saxe's form-function shift framework. It describes how social constructions, conventions, and systems of representation (e.g., currency, games) are restructured through social participation, taking on novel functions.

Although applied to the same corpus of video data, these two frameworks result in vastly different units of analysis. CE leads us to code for moments when parent-child dyads' conversations become "elaborate" by an

expansion of details. As our analysis progressed and we re-watched videos, we learned that we needed to refine our codes so that our units were coupled with the particular exhibited objects that parent-child dyads were visually attending to, as different objects afford different kinds of elaborations. In this instance, while our theoretical framework and research questions governed what we coded for initially, we used feedback from our video recordings to iterate on our codes and refine our units of analysis. Even within the same framework, units of analysis can change because of what video data reveal about the phenomena under investigation.

In the process of conducting our analysis using the CE framework, the wide range of social interactions and the concrete details of the physical artifacts present in our video recordings allowed us to conduct a secondary analysis, ask new questions of these data, and apply a new theoretical framework—cultural forms. In particular, we became interested in how parent-child dyads were adopting and potentially restructuring different design elements in the game to advance through its levels. Consequently, we coded how parent-child dyads' used game pieces, interpreted rules, and applied strategies to maneuver through the game. Using cultural forms as an analytic lens led us to code a different set of episodes than we were coding under the CE framework.

Given the multiple possibilities for units of analysis in video data, reliability and representation become increasingly complicated. As a field, we struggle with making analytical decisions explicit in a way that communicates reliability and representativeness of our claims. Here, we present a definition of reliability that includes explicit criteria for "fuzzy" reliability, to help us move towards increased rigor in analytic claims.

To ground this discussion, we used analysis of video data collected from science classrooms, as a part of a study examining how students learn to engage in scientific practices in meaningful ways. As in the work described above, we found decisions about what counts as a unit to be as consequential as decisions about which code(s) should be applied to the unit. As a result, we spent a significant amount of time coding for, discussing, and checking for agreement on the identification of units themselves. These checks for "fuzzy" reliability relied on heuristics for determining whether we were seeing the same things in the data. Figure 2 illustrates what this process involved. In this case, we used three checks for "fuzzy" reliability early on in the coding process, to ensure that we agreed on the same instances for further analysis. Once we agreed upon those instances, we coded them and used traditional calculations for reliability. In addition, the "fuzzy" checks provided leverage, in thinking about and communicating representativeness. They served as a trace of our work through the data that allowed us to not only talk about how representative a particular code was within the set of coded episodes, but also to discuss in a multi-tiered way how representative those episodes were within the dataset.
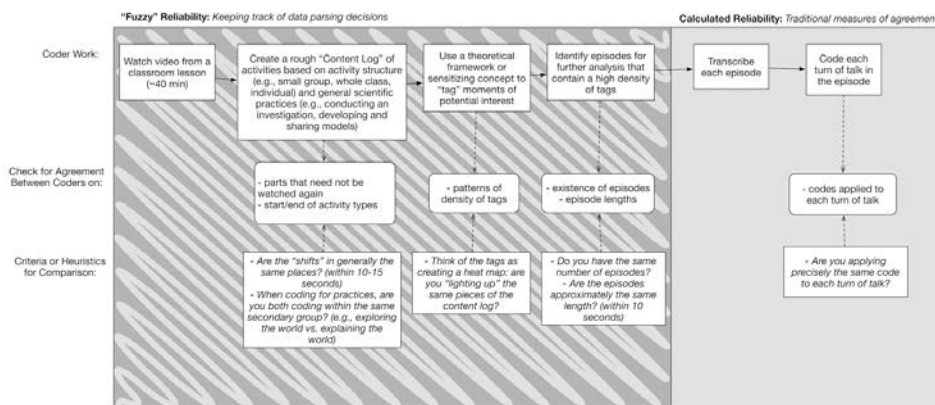
Figure 2. Sample heuristics for comparison of coding decisions in the video coding process.

Lessons learned

Video data provide a range of possibilities for units of analysis and give researchers opportunities to conduct rich secondary analyses. The work described here highlights how the operationalization of theoretical frameworks during iterative processes of analysis influences the ways in which researchers develop and refine units of analysis. The connection between analytic frameworks and units of analysis should be made explicit when presenting data, as it greatly influences the nature of our findings. However, acknowledging different units for different analyses provides additional challenges with regards to reliability. We have drawn attention to a second version of reliability, a "fuzzy" reliability, that involves tracking and checking for agreement on multiple analytic decisions about units of analysis before relying on traditional statistical calculations of reliability .

Representing context

Dionne N. Champion and Elizabeth B. Dyer, Northwestern University

A broad range of work in the field (Vygotsky, 1978; Scribner, 1984; Lave 1988; Hutchins, 1995) has shown that to fully understand how people learn, it is important to look beyond the individual, pointing to the importance of understanding interactions and relationships between individuals, artifacts, and social groups. Because video is a comprehensive data source—simultaneously capturing talk, gaze, gesture, movement, and interactions in a format that is available for repeated viewing—it can be an ideal source for capturing and analyzing context. However, video data can easily become overwhelming to the researcher who must sift through hours of video, deciding which details of the context are significant. In this paper, we introduce strategies for grappling with these issues as we consider context in the analysis of learning events in situ. We draw upon ideas from Actor Network Theory (Latour, 2005), a social context theory which suggests that researchers interrogate their data without presupposing an understanding of which factors matter, and instead look closely at what is happening and trace the observable associations. This stance is essential to understanding the whole story told by the data.

In order to provide a context for this discussion, we share examples from video data collected during an informal, in-school STEM learning program for 5th and 6th grade students. The setting has a complex activity structure, in which all participants engaged in different activities in a variety of ways. The activities were emergent, interest-based, and child-driven, with little teacher direction. The semi-structured activities gave students freedom of choice for decision-making and interaction. Video data in this context was collected both by a whole room, stationary camera and by focal students wearing visor cameras.

Accounting for multiple perspectives

Research on collecting video data has established that video is not a "neutral" source of data; inherent in the collection of video is the perspective of the camera and the researcher's decisions about which perspective to foreground in the data (Derry et al., 2010; Goldman, 2007). Although the collection of video inherently influences the perspective of the data collected, video can still allow for flexible perspective-taking during analysis. In our process of analysis, clips are selected based on research questions or on emerging themes discovered in the data. Methods of interaction analysis (Hall & Stevens, 2016) are used to understand what is consequential to the task or to a participant's goal in a moment of interest, and micro-analysis leads to choices about what is important to trace. From there, the view is expanded by looking at other related clips and/or camera angles. Some examples of expanding the view include: tracing what happens just before or after the moment of interest; close analysis of other participant views (e.g. from other participants wearing visor cameras) to fill in details about interactions with others; and analysis of wider angle perspective cameras to trace participant pathways and association networks.

Our example, partially transcribed below, demonstrates the value of considering multiple perspectives. It involves two boys wearing visor cameras, one who seeks out the other for help.

1	Akeem: Okay- Oh no, oh no! I'm gonna walk.	(*Walks across the room to Benji and Evan*)
2	Akeem: Hey we're camera bros! What's up	(*Reaches across Evan toward Benji's face, to high five Benji*)
3		(*Benji looks up awkwardly at Akeem*)
4	Akeem: Uh can you help me with something?	
5	Benji: We're working...	
6	Akeem: Okay I'm gonna ask Brian.	(*Walks away from Benji and Evan*)

This first transcript excerpt is taken from the point-of-view camera worn by Akeem. A close, multimodal analysis of this perspective allowed the researcher to attend to Akeem's talk, to his focus as he works, and to his level of engagement in the activity. It also allowed the researcher to see both a first-hand perspective of the materials and other actors integral to his process and the moment when his request for help is shut down (line 5). If focusing only on the initial perspective, the researcher could conclude that Benji had no interest in helping Akeem. In order to incorporate the context surrounding Akeem's request for assistance, it is helpful to analyze the actions of multiple participants, as well as the more complete picture of what is happening in the room. Widening the lens by analyzing data from multiple cameras helped to paint a fuller picture of this event.

Benji's Perspective	Akeem's Perspective
Benji: We got it! So where do we tape the thread?	Akeem: I'm gonna walk (*walks across the room*)

Evan: Okay, so...
Benji: Feel free to flip the light and tape the thread to-   Akeem: Hey we're camera bros! What's up
                                                              (*reaches across to high five Benji*)

Benji: *(looks up awkwardly at Akeem)*   Akeem: Uh can you help me with something?
Benji: We're working together right now

Including Benji's perspective, as captured by his visor camera, in the analysis helped clarify his response and brings some context to his decision to say no. The added perspective helped the researcher understand that Benji was highly engaged in his own process at the time of Akeem's question and Akeem's presence constituted an interruption in his work flow, which could explain why the request for help was not taken up.

Dynamic representations of context

Video allows for the creation of both specialized static representations (e.g. multimodal transcription, journey maps or activity maps with interactional details inserted) and dynamic representations which can include pathway traces, side-by-side or split-screen video, GIFs, and time lapse video. Time scales can be altered to create representations of video data that can be helpful for analysis. Slowing down time can elucidate what is happening on a micro-level in a short clip and speeding up video clips can help researchers trace trajectories of phenomena over longer periods of time. For example, short video clips collected from multiple classrooms in the STEM study were placed side by side and played in fast motion to display patterns in the children's movement and behavior. Watching the fast motion clips side by side highlighted differences in the activity structure, and allowed us to see how drastically it had changed by the middle of the school year. Representations can be used to get a clearer understanding of the context, and decisions about the most appropriate and effective representations are likely to change as the understanding of the data evolves. In the case of understanding the complex activity systems in our examples, experimenting with different representations has been essential to recognizing patterns and understanding what important things may be missing from the story.

Lessons learned

Capturing visual details makes it possible to consider the context surrounding events and allows for a more complete understanding of the moments of interest. We suggest that researchers who engage in video analysis select different representational forms, play with changes in time scale, and use multiple perspectives to make sense of data, keeping in mind the importance of allowing the whole story to unfold. These manipulations in the representation of context can help focus researchers on salient aspects of context in new ways throughout analysis. Flexibility among representations can allow researchers to consider context in a multi-faceted way.

Conclusions and implications

This symposium contributes to the learning sciences by providing theoretical and practical standards and heuristics for addressing the unique affordances and challenges of the *process* of video analysis, as well as explicating reflexive connections between these theories and methods. These standards and heuristics are at a smaller grain size than overarching themes or guiding principles; they are theoretically-grounded criteria that guide individual analytic decisions. This contribution to learning sciences theory and methodology is timely, as researchers in our discipline increasingly rely on video records to capture and analyze the processes of teaching and learning. It is important, given that the affordances of video and its varied uses in research are consistently outpacing the development of theory and methodology surrounding this medium. Our theoretically-guided set of standards and heuristics, drawn from a diverse group of researchers, research projects, data corpuses, and research questions, contribute to the development of rigorous analytic standards for video research.

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Acknowledgements

Connected Making: Designing for Youth Learning in Online Maker Communities In and Out of Schools

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Abstract: While here is ample research on how youth are connected in online spaces and how youth participate online via sharing and reviewing artifacts, yet less is known about how these social connections and contributions emerge, especially in the context of physical making and what can they contribute to learning and assessment. Thus, our symposium primarily addresses two questions: (1) How do youth connect and learn in online maker communities? and (2) How can we design online maker tools *for* learning in and out of schools? We share efforts examining how sharing artifacts, documenting design processes, and providing feedback via online tools can support young makers in creating physical artifacts and offer insights to new assessment models.

Introduction

New technologies (e.g., mobile devices) and platforms (e.g., Internet forums, social media and other online spaces) are making the Internet not only more accessible but also keeping youth connected with each other across time and space. These online tools and communities have been dubbed one of the main propellers of the maker movement in education that advocates learning through making, building, tinkering, playing, and creating three-dimensional objects and installations (Dougherty, 2012). While there is much research on how youth are connected in online spaces (e.g., Ito et al., 2008; Jenkins, 2006) and how youth participate online via sharing and reviewing artifacts (e.g., Brennan, Monroy-Henadez, & Resnick, 2010), less is known about how these social connections and contributions emerge and how they can be supported for youth engaged in physical making. In this symposium, we bring together current efforts to review the critical element of sharing and providing feedback (Paper 1), encourage youth to take ownership over their learning through documentation (Paper 2), support learning through sharing, commenting, and connecting (Paper 3), and establish portfolios as an assessment model (Paper 4). The studies are collectively drive by two primary questions: (1) How do youth connect in online maker communities? and (2) How can we design online maker tools *for* learning in and out of schools?

Our symposium addresses how we can leverage online tools to support young makers' physical making in and out of schools. To begin, Fields and Grimes outline the landscape of how youth use online tools in the wild. Their findings survey youth participation in over 120 DIY sites and the tensions of designing online tools for youth that not only support sharing but also other forms of social networking such as commenting and critiquing. The next three presentations will each showcase a different design-based approach on how to provide essential social networking supports for making: Halverson and colleagues review efforts in public library system that encourage youth to take ownership over their drop-in work at their makerspaces. Litts and colleagues designed an online platform to connect makers locally and globally and foster interactions around maker activities within school settings. Finally, through the Open Portfolio Project Peppler and colleagues investigate a range of ways to document making and learning in the making with a particular focus on assessment within the context of a community center. Each study sheds light on a different dimension of how to design online maker tools and communities for learning by sharing, documenting, and giving feedback on physical maker artifacts.

A comparative study of child-inclusive DIY media websites

Deborah A. Fields and Sara M. Grimes

One of the most important aspects of the do-it-yourself (DIY) media trend is the way it has increased children's access to tools of "mass" distribution. Whereas child-made media was once relegated to refrigerator doors and classroom bulletin boards, it can now be published on shared, public venues. From an educational perspective, this shift has the potential to open up a number of social learning practices for children online, building on long-acknowledged aspects of learning including developing technical and artistic skills in community, fostering identity creation and self-expression, and encouraging creativity (e.g., Buckingham, 2009; Vygotsky, 2004). At the same time, designing websites for children is situated in a number of larger issues that influence those designs including legal and policy issues; commercial influences and advertising; and hierarchies of access arising from different funding models and safeguards (Grimes & Fields, 2012). To date, much of the scholarship on kids online has focused on single websites, some of which were developed under highly unique circumstances—such as out of a university (e.g. *Scratch*), or through a special funding initiative (e.g. *YouMedia*)—leaving a dearth of comprehensive and comparative research in this area.

Now in its second year of research, *The Children's DIY Media Partnership* seeks to identify the types of support systems—regulatory, infrastructural, and technical—that most effectively and sustainably foster a rights-based, inclusive, child-centric approach to addressing children's cultural participation online. As a first step, we conducted a media scan with the goal of finding all available, English-language websites where children could make and share media content that they themselves had created. While this included intergenerational websites, we focused on searching for websites targeting children under age 13 a neglected population in research on kids online (Grimes & Fields, 2012). The scan was conducted using multiple search engines (i.e., Google, Bing) and search terms by different researchers on multiple browsers. A thorough search identified 140 websites that allowed children to share content that they made (see Grimes & Fields, 2015). Of these, 100 were open or public spaces. The remaining 40 were closed to children only, and of these, 20 sites gave us permission to research their website designs (a requirement of our Institutional Review Board). The contents of the 120 sites were recorded using a standardized, 83-item coding protocol, developed collaboratively by the entire research team over the course of four months and several iterations. Three researchers coded the websites after achieving a 93.7% inter-rater reliability. The content analysis included elements of the sites' designs (particularly the mechanics and features involved in creating and sharing user-made media), descriptive texts (e.g. About Us pages, instructions), advertisements, funding models, terms of service, and privacy policies.

One of the most unexpected findings emerged from the media scan search: relatively few sites that allow children contained sharing features. A great number of early search results were ultimately eliminated because they failed to provide tools or mechanisms for sharing content. These sites provided media making tools, instructions, or resources to help kids create media without any tools or support systems for distributing or sharing that media with other users, or with the broader public. In addition to the multitude of websites excluded during the scan itself, another 107 sites (nearly half) were eliminated during the early stages of the content analysis. Although sharing was mentioned in the sites' descriptions, the sites themselves contained no built-in support for publishing and distributing content. In terms of design, "making" trumped "making and sharing" in the sites available for children.

The content analysis revealed a number of interesting trends. As an example we present some of the findings related to the display and support of community on the main pages of the websites: the very mixed visible representation of community, community activities (versus individual contributions) and support for community participation. A number of sites had some sort of *representation* of *community* participation, mostly in terms of displaying some users' shared content (65%), featuring individual user profiles (23%), and in a few cases showing the results of user polls (9%). However, even when other members' projects were shown, these were not often displayed in ways that made navigating them easy. Features such as tagging, following, or gathering sets of projects (for instance in a gallery) were rare. Further, more than a quarter (26%) of the websites surveyed did not display any community features at all on the homepage. About half of the sites featured some sort of *community activity* such as hosting competitions, contests or challenges (49%) or displaying group projects and collaborations (30%). Sites seemed to struggle especially with providing a means for providing *community support* to users. The most common form of support was user forums (44%), with a few websites hosting peer reviews, awards for user participation, or encouraging in-person meet-ups. Additionally, while most sites (69%) provided tutorials through recordings or embedded guides for users but lacked ways to support users socially. All of these findings show that a large proportion of children's DIY media websites are not well designed to support navigating projects, finding others, and building interest-driven relationships.

Overall the findings show that in many of the sites examined, sharing content with the public and sharing ideas with other creators were not sufficiently supported in the sites' designs. Since sharing and interacting with others is important to so many of the benefits associated with media-making, from the development of 21st century

literacies to children's cultural and communication rights, this omission is concerning. At the same time our research did reveal a few unusual sites that explored creative models to socially supporting children's media-making online, including a site that incorporated creative commons licensing, as well as a few sites that facilitated peer mentoring among users. This demonstrates a need for discussions with designers, businesses, and policymakers about supporting the development of richly designed websites for children's media making, sharing, and community. Providing a means and support for children to respond to authentic audiences, share ideas, and give and receive constructive feedback is important to truly making the most of the distribution channels available in social media.

Technologies for learning in library-based makerspaces

Erica Halverson and Mike Tissenbaum

Libraries have become sites for pushing the boundaries of informal learning. Once almost exclusively sites for accessing information, many public libraries are redefining their mission and core services as places for learning, creating, and sharing. The Maker Movement has proved a great catalyst for integrating engaged learning experiences into libraries; Britton (2012) describes makerspaces as, "a natural extension of library services" (p. 32). In a meta-analysis of the relationship between makerspaces and public libraries, Willett (in press) highlights shared core values including a DIY ethic, open access to peers and information, and an emphasis on attracting traditionally non-affiliated populations. It is within this context that we are conducting a two-year study with the public library system of a mid-sized Midwestern City to understand: a) How to make "making" a core service across the library system and b) What people who participate in the making activities and maker culture of the public libraries learn as a result of their engagement. Early findings from our ethnographic research have revealed three problems with addressing *learning* in the context of our library makerspaces:

- A focus on drop-in programs means that maker experiences are routinely introductory and therefore do not expect participants to connect experiences together;
- There is no mechanism for tracking individuals' work;
- Expertise is often contained within the drop-in program and very rarely persists beyond a single space or an experience.

Despite these challenges, library staff are motivated to create learning experiences for participants that are grounded in what we understand about how people learn through making (Bevan, Gutwill, Petrich, & Wilkinson, 2015; Peppler, Halverson, & Kafai, in press). As a result, we have worked together to design and integrate technological tools into a range of maker programs.

Connected peer spaces framework

The "Connected Peer Spaces Framework" (CPSF) is is a lightweight technology framework that logs an individual participant's presence (using either RFID or Bluetooth) in any makerspace within a network of makerspaces and tracks their current making activity as well as the growth of their personal learning trajectories and "maker skills" acquisition. Participants' data is represented in the space through a series of ambient dashboards situated in each of library spaces where maker activities occur. These relatively minimalistic dashboards show the real-time activities of the participants across all of the connected spaces, as well as the "maker proficiencies" they have developed over time and enable low-latency low-friction videoconferencing. These representations are designed for learners to be able to evaluate potential productive peers and easily connect with them. By providing this information CPSF attempts to answer the two main challenges described above: 1) Giving participants insight into the skills of their peers to help know who to reach out to when they need help with a specific maker-skill related problem (e.g., 3D Printing) and; 2) Giving them a sense of the broader making community of which they take part.

As part of this symposium, we will share our findings from the deployment of CPSF at a series of 3-day summer "maker camps" and through individual workshops at a range of library locations. We find a tension between participants' desire to be connected with others who are working with the same materials and tools as they are (e.g. Minecraft, knitting) but a strong distaste for being "tracked", something that the library has traditionally avoided. We are continuing to iterate the design of CPSF to afford connections, distributed expertise, and broader sense of community across the city.

Build in progress

We have also worked with libraries to incorporate Build in Progress into more extended maker activities. Build in Progress (BiP), a web-based-platform for makers to document and share their design process (buildinprogress.media.mit.edu). BiP allows participants to capture their personal experience of developing a project, including setbacks and changes over time. These iterations and communal commentary are visually organized using a two-dimensional tree structure. Since the BiP website launched two years ago, over 750 projects have been shared, ranging from "EL Wire Boots" to "Making Soda." The site has been developed iteratively, building on studies of how users engage in design processes and synchronous and asynchronous communication as the means to continuously develop BiP's features (Tseng, in press). The developer's investigations into how users understand their motivations for openly sharing their design process, the strategies they use to solicit feedback from other makers, and the role that visualization can play in encouraging reflection, parallel our work.

The emergent themes found in BiP research such as documenting-in-action (using process-oriented documentation as a dual planning and reflecting tool), vulnerability in sharing design process (in order to help others or seek advice), and documentation as its own form of creative expression and identity representation, are intimately connected to the challenges we have identified in the library makerspaces. Here we share the design features of BiP as well as our pilot efforts to incorporate the tool into digital making experiences at the libraries to scaffold iteration, ideation, and critique encourage participants to extend their making experiences over time and place. Bringing BiP to library makerspace settings combines the expertise of on-site experts and facilitators with documentation software that serves as an ongoing portfolio of project development. From a research perspective, the software environment allows the tracking of how the use of such software impacts makers' learning, development, and self-efficacy and the role asynchronous documentation might play in the makerspace environment.

Library makerspaces are one example of a growing category of "drop-in learning environments", where a persistent challenge is how to encourage participants to take ownership over their own learning. As learning scientists, we view learning as involving some kind of change - cognitive, behavioral, distributed, or sociocultural - where participants are different than they were before the experience. Furthermore, we believe that this change out to be documentable, something that can be shared with others. This research aims to create a sociotechnical system that both values change and provides opportunities for learners to document these changes in a way that doesn't betray the library's history of providing a safe space for patrons to access information without feeling tracked. We hope this research opens up a conversation about the role of technologies in creating opportunities for ownership over maker learning processes.

Designing for connected crafting: Using an online platform to support maker activities and communities

Breanne Litts, Yasmin Kafai, and Orkan Telhan

Much of the recent research on online DIY sites, participants, and activities has focused on understanding social dynamics, motivations and challenges in self-organized online or offline maker communities. Extensive surveys have examined what motivates members to participate and share projects in DIY sites and communities like *Instructables, Dorkbot, Craftster, Ravelry, Etsy*, and *Adafruit* (Kuznetsov & Paulos, 2010). Other have conducted more ethnographic observations to understand the contributions of experts in local maker communities (Milne, Rieke & Antle, 2014) or focused on motivations of how and why makers search for craft knowledge on the web (Torrey, Churchill & McDonald, 2009). The findings from these studies reveal that not only producing an artifact but also sharing the design process and final artifact with others are driving forces for makers' participation in DIY activities, spaces, and communities (see also Gauntlett, 2011).

Research on designing and supporting learning in educationally-oriented DIY efforts and makerspaces is just beginning. Most relevant to our efforts is the earlier design (and failure) of designing a web community, called *Lilypond* (Lowell & Buechley, 2011), that was intended to offer a home for designs made with the LilyPad Arduino. After a three-year run, the site had hundreds of e-textile projects of varying difficulty levels, but most of these were uploaded with very few of the interactions that make sites like *Ravelry* or *Instructables* not only repositories but also social networks of makers. It is not clear how social connections can emerge in the design of online DIY communities with an educational focus. So far most popular DIY online communities have evolved organically from makers' interests. While the communities use web portals to communicate and coordinate design activities, the platforms themselves do not deliberately address the needs for connected making such as allowing members to build on each other's work, share know how, and critique each other's design to foster new iterations.

We created a platform, *Ecrafting* (ecrafting.org), that affords multiple ways for participants to engage with one another around making: calls, circles, and projects (Telhan, Kafai, & Litts, in press). The platform facilities interactions among participants through *calls,* which are theme-based announcements for maker events,

activities, and challenges. This allows members across previously established groups to participate in each other's events either by attending in-person or discussing online. Moreover, the calls are mapped onto a timeline so that makers can anticipate upcoming events and plan new ones. The *circles*, a concept inspired by traditional quilting and knitting circles, can be created either by institutions who support structured curricular activities or by interest groups or individuals who organize informal gatherings.

Our design-based study investigated how aspiring makers can use the *Ecrafting* platform before, during, and after their activities to facilitate critique-style discussion around students' projects. We implemented a workshop with sixteen high school students, between ages 14-15 years, in which they designed a human sensor project using the LilyPad Arduino, an electronic textile construction kit. During the design process for their human sensor projects, we invited students to share examples of their initial project designs on *Ecrafting*. Three graduate students, who were enrolled in a more advanced in electronic textiles at a university in the western United States, gave online feedback to each project. The high school students continued to work on their projects and integrated the feedback they received where they felt necessary. When they completed their projects, they shared their final artifacts with a description on *Ecrafting*. In interviews after the project, even if students did not explicitly integrate the online feedback into their projects, they all reported that the feedback process was useful and valuable either serving as an encouragement, constructive correction, or creative suggestion for the future. For instance, Gannon, a student who remixed the triforce logo from The Legenda of Zelda, reflected on receiving online feedback:

> It was very encouraging actually. I didn't actually expect to get my work published online so that other people who honestly know more about this could see it. I thought it would just be in our little group every day at the [science museum]. It was definitely something that changed me... One of [the comments] was very encouraging saying that this is a great project and I should just keep going with it, everything is fine. The second one was saying that my wiring was confusing, and it was so I flipped the LEDs and I changed my wiring and it looks a lot better.

Here we saw the critical value that social interactions and feedback can provide to aspiring makers. The design of the *Ecrafting* platform connected online and offline maker activities. After completing a few of these types of user tests, we began to redesign the platform to support specific forms of interactions, namely, sharing and critiquing maker activities. The redesign is an ongoing effort we are testing with nine graduate students enrolled in a maker studio course at a university in the northeastern United States. We are adding and testing several new features, but here we highlight *project sharing* and *project iterations*. From user testing, we learned that there were too many obstacles preventing users from submitting projects in response to calls, so as part of the redesign we are streamlining this process and allowing new users to respond to a call with a project even if they are not part of a circle. Originally, we designed *Ecrafting* to start locally and expand or continue online, but we identified a need to better support participation that begins online. Moreover, we realized that if we wanted to support dialogue around projects, then we needed to allow users to easily submit multiple iterations of a single project, so that they can report their progress and continue receiving feedback. We want to make sure that an online platform for a maker community can function not only as a repository, but also as a social networking forum in the process of making.

Maker portfolios: Documenting and assessing making

Anna Keune, Kylie Peppler, Stephanie Chang, and Lisa Regalla

> *T-shirt tucked into jeans, Elliot leaned over Jabari's computer screen pointing at the village he discovered in the networked virtual reality game that they and a handful of other makers were engaged in. When documenting his digital making, Jabari augmented screenshots of the village with words: "I feel that everybody contributed equally because we split up the work."*

Encouraging peer-reflection of learning through artifacts and evidence of learning is a key catalyst for learning environments that foster critical literacy skills (Hetland et al., 2007). This is closely tied to the interest-driven, production-based learning that can be observed when youth make together (Peppler, 2014). More than 20 years ago, Niguidula (1993) convincingly presented the need for showing the richness of a person's accomplishments, work, and learning beyond standardized test scores, suggesting that digital portfolios that emphasize student work in context and engender an understanding of what it means to be a graduate could provide this richer picture. Today, the work on portfolios gains new traction in the context of making and youth-serving makerspaces as makers' portfolios become important parts of both higher-education and job admissions processes outside of the

art and design tradition (Byrne & Davidson, 2015). With makerspaces serving socio-economically diverse youth (Peppler et al., 2015), espousing maker portfolios promise to broaden access to economic and educational opportunities. What youth document today can dramatically shape their access to diverse opportunities in future phases of their lives.

To broaden our understanding of high-quality maker portfolios, what they may include, and how they may be assessed, we conceptualize maker portfolios as a portfolio *system*, in which makers maintain control over content and curation. Challenges for youth to create maker portfolios pertain to policy, practice, and tools. Although we know that learners achieve best when their learning is connected across multiple settings (Ito et al., 2013), we observed that youth are often disenfranchised from their work, with artifacts stranded in systems owned by schools or in platforms that do not allow for easy or automatic migration over time. Additionally, in the flow of making, makers often want to keep doing what they set out to do, rather than pause for documentation. This places a core tension on balancing automated and manual documentation with least disruption of making and just enough data collection. These challenges are connected to hardware and software challenges to build on the mobility of making. Among others, these challenges prevent youth from creating rich portfolios of their learning and from prompting assessment that could make the youth's accomplishments relevant for future life phases. To understand successful portfolio practices and assessment, we ask: What practices and types of portfolios lead to high quality documentation of making and promote the assessment of rich learning?

To answer this question, we observed the native portfolio tools and practices of two makerspaces that have exceptional portfolio practices in place. Through synchronous and asynchronous engagement with the makerspaces, we selected youth who were particularly engaged in portfolio creation, observed the digital portfolios of the selected youth, took snapshots at regular time increments, analyzed changes in their documentation over time, and observed their practices on site. To triangulate and complement the observations, we conducted interviews with parents of the focal youth and makerspace educators. The interviews included questions related to adult support for documenting, values of portfolios, and hypothetical questions for parents and educators to imagine themselves in the role of an admissions officer assessing youth portfolios.

Looking across observations and interviews, we identified two intersecting axes in relation to which we characterize and highlight maker portfolios and the assessments they prompt. The axes stretch from collaborative to individual making and from collaborative to individual documentation. While all portfolios gave youth a chance to present their products and processes of making, some painted a richer picture of learning than others. Individual making, paired with individual documentation, frequently focused on reflection of the technical aspects of making rather than rich insights that sprang from peer interactions. This was contrasted by individual portfolios that captured making done collaboratively. Here, technical process reflections were often augmented by displays of how small groups of makers worked together and contributed to projects, prompting answers to questions about how well a prospective candidate might fit into the culture of a college program or work place. This addressed challenges of assessing collaborative making that is documented collaboratively, namely the uncertainty of one individual's contribution to the group's work. While the makerspaces we profiled offered youth the opportunity to create their own personal websites to document making, spaces also integrated the individual sites into a collage of youth projects, representing the collective learning of the space to outside viewers. This gives potential employers or higher education institution admissions officers the opportunity to see a youth's portfolio in the context of the overall work done at the applicant's affiliated makerspace. In the nascent maker movement, where definitions of making expertise diverge, our findings point to the need to take a broader look at assessment, one which encompasses ongoing and casual everyday practices by adults and youth at makerspaces. Specifically, our work also points to the importance of collaboration in making as a way to lead to higher quality portfolios that prompt assessment of the rich learning.

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Agentive Learning for Sustainability and Equity: Communities, Cooperatives and Social Movements as Emerging Foci of the Learning Sciences

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Abstract: This symposium expands the object and scope of the learning sciences by introducing communities, cooperatives and social movements as crucially important sites of learning. The symposium papers employ and critically interrogate cultural-historical activity theory, specifically the theory of expansive learning, and the emerging methodology of formative interventions as a potential framework for dealing with learning in communities, cooperatives and social movements. Expansive learning emerges as a process of revitalizing the commons, or commoning. The contributions of the symposium point toward the importance of analyzing and fostering transformative agency as a quality of learning.

Overview of symposium

Evidence suggests that we have only years, not decades, to restore the balance before we tip the planet's natural systems into irreversible cycles that will wreak havoc on vast swathes of nature and on the lives of billions of people around the world. The looming global environmental crisis requires learning and agency that go beyond and across the confines of disciplines, age groups, institutions and cultures. Such learning and agency building must be part and parcel of efforts to create and maintain sustainable and equitable forms of livelihood and communal life, that is, alternatives to capitalism as we know it. It is the task of engaged researchers to identify, analyze and foster them.

We need to celebrate instances in which we see the market being effectively reembedded in civil society—where investment and production decisions are being driven by social needs rather than private-profit considerations. Where city governments team up with local credit unions, pension funds, and unions to support the emergence of local cooperatives, where these cooperatives join together in planning processes that involve the local community, where these cooperatives' products respond to real economic, social, and environmental needs as determined by the people involved. Alternatives to capitalism also emerge within established institutions such as education and health care, as innovative alternatives to privatization and commoditization.

Here, even if the experiments are local in nature and far from the global scale we so urgently need, people can at least begin to see the contours of the kind of world we need to create. There is an impressive range of such new democratic institutions and institutional ecologies that have been quietly developing just below the surface of public awareness in recent years. They presage various ways of reembedding the economy, not as a return to pre-capitalist modes of embeddedness, but as the creation of a new form of society in which economic decisions are made under norms of democratic dialogue (Adler, 2015).

The notion of reembedding the economy is closely related to the notion of expanding the commons, or commoning (Ostrom, 1990; Linebaugh, 2008). The notion of commons refers to the cultural and natural resources accessible to all members of a society, including natural materials such as air, water, and a habitable earth; these resources are held in common, not owned privately. Also knowledge itself needs to be understood as commons (Hess & Ostrom, 2007).

This view calls for reorientation of educational research toward the dialectics of agency and transformation in activities and communities in turmoil. Such a reorientation involves two major shifts. The first shift is moving beyond (but not excluding) classrooms and schools, toward communities, work activities and social movements as sites of learning. The second shift is moving beyond observations and analysis toward theoretically grounded interventions. The key ideas of such a reorientation include the following:

- Learning and formation of agency are seen as intertwined processes; transformative agency is a central quality and outcome of learning.

- Schools are seen as nodes in a community or network of diverse activity systems struggling to learn a new way of living.

- Learning and instruction are seen as increasingly horizontal processes of sharing and hybridizing – vertical processes cannot be regarded as self-evident or superior.

- Learning and instruction are seen as part and parcel of longitudinal efforts to build sustainable and equitable ways of life; short episodes or courses of school learning need to be seen as special cases embedded in long-term processes of transformation.

- Learning and instruction need to be built on the histories and indigenous funds of knowledge within communities.

- Learning and instruction need to be re-connected to their driving forces, namely vitally significant contradictions and efforts at their resolution in the lives of communities.

- Research on agentive learning for sustainability and equity in communities and activity systems such as cooperatives and social movements is typically conducted with the help of formative interventions; methodologies of intervention research are of foundational importance for this field.

These challenges are addressed in four papers and a commentary, presented by scholars coming from five continents. In the first paper, Yrjö Engeström and Annalisa Sannino (University of Helsinki, Finland) propose a conceptual framework for studies of agentive learning in communities and social movements as an agenda for the learning sciences. In the second paper, Aydin Bal (University of Wisconsin, Madison, USA) will present findings from Culturally Responsive Positive Behavioral Interventions and Supports (CRPBIS), a statewide formative intervention study. In the third paper, Heila Lotz-Sisitka, Tichaona Pesanayi and Charles Chikunda (Rhodes University, South Africa), using conceptual tools from cultural-historical activity theory (CHAT), analyze learning in two sustainability-oriented commonality building activities, namely co-management of natural resources and communal food gardening. In the fourth paper, Manoel Flores Lesama, Antonio Carlos Picinatto (both from the Federal University of Paraná, Brazil) and Marco Pereira Querol (Federal University of Sergipe, São Cristovão, Brazil) analyze the learning challenges involved in the emergence of a rural credit cooperative in Brazil. Yew Jin Lee (National Institute of Education, Singapore) will serve as discussant of the symposium.

Agentive learning in communities and social movements: Toward a research agenda

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Is educational research effectively responding to the acute worldwide challenges of equity and ecological sustainability? We address this question in dialogue with recent analyses (e.g., Scott, 2015; Wooltorton & al, 2015) which claim that scholarly work in education should be more relevant and engaged in supporting transformative agency emerging in the struggles for fundamental human rights. A theoretical and methodological argument is developed drawing on data and findings from an ongoing research project on learning in productive social movements. The paper argues for interventionist studies that build on the interconnected categories of alienation and transformative agency in analyses of expansive learning.

Theoretical framework

The philosopher Sève (2012) defines alienation as a foundational category of dialectics having both an ontological and a gnoseological scope. This category allows one to grasp the historical development of human beings and provides methodological insights for investigating this development. Alienation is a result of the separation between productive work and social wealth established by the capital throughout history. Within alienated activities intrinsic antagonistic forces are at play: On the one hand, the conditions of production and development separated from individuals turn into subjugating forces; on the other hand, an unlimited emancipatory development of all forms of social wealth gains momentum. Within this dialectical perspective, alienation both prevents and generates transformative agency. Alienation and transformative agency form a dialectical unity of opposites.

In the theory of expansive learning (Engeström, 2015), learning is seen as qualitative transformation of collective activity systems, such as work units and communities. Expansion refers to a type of learning in which the object of the activity is qualitatively widened and nobody knows ahead of time what exactly needs to be

learned. Expansive learning leads to the formation of a new, expanded object and pattern of activity oriented to the object. Three ideal-typical phases of the formation of the object in expansive learning may be identified, namely 1) emergence of an initial diffuse object; 2) formation of a consciously articulated, abstract *germ cell* object, and 3) construction of a concrete expanded object. In focusing on the learners' work to grasp and transcend the contradictory unity of alienation and transformative agency, the paper takes a step forward in the development of the theory of expansive learning.

Three cases

The aim of this study is to identify dynamics that trigger, sustain or prevent expansive learning in social movements facing major challenges of survival and sustainability. Our aim is also to understand how productive social movements may stabilize their achievements and accomplish longevity.

Our first case is the *Campesino a Campesino* movement in Central America (Holt-Giménez, 2006). This is a large-scale movement which develops sustainable forms of livelihood for poor farmers, challenging the dominance of industrial forms of agriculture and food production owned by large corporations. In doing this, the movement has developed an entire pedagogy based on horizontal interaction between farmers.

Our second case is the Herttoniemi Food Cooperative in Helsinki, Finland. Founded in 2011, the cooperative brings together consumers seeking reliable supplies of organic and nearby food, and agricultural producers of such supplies. The cooperative has about 200 members. It rents a field 30 kilometers from the center of Helsinki where a hired farmer produces vegetables for the cooperative. During the harvest season, vegetables are transported weekly from the field into the city to distribution points where members can come to pick up their share. In spite of its growing popularity, the continuity of the food cooperative is constantly at risk. Small-scale ecological farming is very labor-intensive and has to compete with the heavily subsidized farm products of large food store chains.

Our third case is the New York City Community Land Initiative (NYCCLI). NYCCLI brings together the homeless of New York and activists seeking to establish novel forms of financing and administering affordable housing. A central aspect of the activity of this movement are diverse forms of popular education and self-education of the homeless, the administrators, and the public at large.

Our analysis will show that these movements are examples of the core challenges facing education and educational research in the 21st century. The analysis of the cases leads us to propose a set of key concepts and criteria for expanded objects of educational research. The analysis also reveals a number of novel potentials for education, as well as methodological challenges for educational research.

Data and methods

The first case is analyzed with the help of the rich historical and ethnographic data included in the pioneering study of Holt-Giménez (2006). The two other cases are analyzed with the help of extensive ethnographic observations and recordings of key meetings collected by our research group. In the analysis of the data, we use the method of identifying discursive manifestations of contradictions (Engeström & Sannino, 2011) as well as the stepwise model of double stimulation as generative mechanism of transformative agency (Sannino, 2015).

Preliminary findings

Each one of the three cases is dependent on learning and instruction, understood as generation of new practices and requisite knowledge. In the three cases, learning and instruction are highly motivated by commoning efforts (Linebaugh, 2008) that stem from contradictions in the lives of the participants. Learning and instruction in these cases are primarily horizontal processes of sharing, combining and hybridizing different kinds of knowledge and expertise. Learning and instruction are longitudinal processes; there are no fixed *terminal objectives*. The movements and communities in the three cases could, however, benefit greatly if schools joined them.

Our findings indicate that the object of educational research and theorizing can and should be expanded along three dimensions: (1) Spatially; learning and instruction need to be seen as increasingly horizontal processes of sharing – vertical processes are merely special cases; schools need to be seen as only nodes in a community or network of activity systems struggling to learn a new way of living. (2) Temporally; processes of learning and instruction need to be seen as part and parcel of longitudinal efforts to build sustainable and equitable ways of life; short episodes or courses of school learning need to be seen as special cases embedded in long-term processes of transformation. (3) Motivationally; learning and instruction need to be re-connected to their driving forces, namely significant contradictions and efforts at their resolution in the lives of communities - drivenness needs to be recognized as a quality of productive learning.

Toward ecological validity and sustainability: Transforming schools from the ground up

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This paper presents findings from Culturally Responsive Positive Behavioral Interventions and Supports (CRPBIS), a statewide formative intervention study. The CRPBIS research team partnered with the Wisconsin Department of Public Instruction, an urban school district, and community organizations (e.g., Urban League, Centro Hispano) to establish an inclusive problem solving process in schools, called *Learning Lab*. The goal of the Learning Lab is to build schools' capacities for equity-oriented transformation (Bal, 2011). Learning Labs were implemented at three preK-12 schools in order to redesign discipline systems with local stakeholders, specifically those who are historically marginalized from schools' decision-making activities. The paper will report on the implementation of a Learning Lab at Martin Luther King Jr. (MLK) High School in the 2013-2014 school year. The author will discuss how Learning Lab members examined the racialization of discipline at MLK and designed a new behavioral support system that was culturally responsive to the diverse experiences, needs, and goals of their school community.

Significance of the study

In U.S. schools, African American, Native American, and Latino students receive suspension and expulsion more frequently and are punished more severely for less serious incidents such as disrespect and excessive noise than their White peers (The Office for Civil Rights [OCR], 2014). Racial disproportionality has an impact on the likelihood of academic failure and involvement in the juvenile justice system (American Psychological Association, 2008). As a systemic contradiction, disproportionality creates a *double bind* for educators - "a societally essential dilemma which cannot be resolved through separate individual actions alone—but in which joint co-operative actions can push a historically new form of activity into emergence" (Engeström, 1987, p. 165). To handle this double bind, schools often rely on federally sanctioned standards-based programs for systems change. Those programs prescribe a *universal* behavioral support model implemented with high fidelity as solutions. The standards-based programs have not improved behavioral outcomes for non-dominant students (Vincent & Tobin, 2011).

Theoretical framework and research questions

Effective and sustainable transformations demand a robust theory of change and building coalitions (Soja, 2010). CRPBIS is informed by Engeström's (2015) expansive learning theory. Grounded in historical materialism, expansive learning theory offers a new methodology called *formative intervention* for facilitating systemic transformations led and owned by local stakeholders (Engeström & Sannino, 2010).

This case study answers the following research questions: *How can the Learning Lab be understood through expansive learning actions? How did the Learning Lab facilitate the creation of a culturally responsive school discipline system at an urban high school?*

Method and analysis

The Learning Lab at MLK was comprised of 14 members: Two administrators, five teachers, five parents, one student, and the director of a local social justice organization. Members met for 11 sessions. Multiple data sources were analyzed including 96 hours of video recordings, interviews, and office discipline referrals. An in-depth qualitative analysis was conducted to trace the expansion of the MLK discipline system through a cycle of learning actions.

Results

Six expansive learning actions emerged in the Learning Lab: *Questioning, analyzing, modeling, examining, implementing,* and *reflecting on the Lab process*. Learning Lab showed promise as a means toward democratization of the school's decision-making process. Overall, the CRPBIS Learning Labs functioned as research and innovation sites for the schools as well as for the research team to develop tools for authentic community-school collaborations. The district is now working with the CRPBIS team to scale up Learning Labs.

Implications

In the age of standardization with the relentless neoliberal attacks against public education, educators in the United States find themselves between a rock and a hard place juggling multiple tasks of the top-to-bottom education reform initiatives while facing lessening opportunities to experiment, reflect on their practice, and collaborate

with other educators, students, and families. The CRPBIS Learning Labs and other grassroots coalitions may provide organic and sustainable ways of re-imagining schools as spaces of solidarity and emancipation.

Building commonality: Navigating historically situated power relations in CHAT expansive learning research

Heila Lotz-Sisitka, Tichaona Pesanayi and Charles Chikunda, Rhodes University, South Africa

Developing activities of protecting, conserving, sustainably using and sharing the commons equitably with due consideration for all people and non-humans has been described in various fora as one of humanity's most pressing challenges, including in UNESCO's most recent document framing the purpose of education and learning for the 21st century (UNESCO, 2014).

We draw on Peter Linebaugh's (2014) analysis of expropriation activities and appropriations of land and common property resources in the English countryside considering these issues as they traverse the rocky historical terrain of colonial Empire Expansion under British, Dutch, French and Belgian colonial rule. Jumping several generations southwards to the southern tip of Africa, we discuss two sustainability oriented commonality building activities, namely co-management of natural resources and communal food gardening. These activities and their emergent development are shaped by mediational and generative research based on cultural-historical activity theory. They are framed as relevant activities in the early 21st century in postcolonial, decolonizing societal contexts, and involve a re-appropriation and a re-claiming of the commons and commonality under complex conditions of climate change and water scarcity (Rittel & Weber's (1973) 'wicked problems' and Engeström's (2009) fourth generation CHAT objects).

The two case studies illuminate how via expansive learning in CHAT generative research processes, communities, formerly disenfranchised and left bereft of land, resources and other means of livelihoods are beginning to reclaim the commons through expansive learning and transformative agency - one bit at a time. The two cases are:

Case 1: A case of emerging co-management activity in the northern part of South Africa in the Limpopo Province, Olifants River Catchment, where communities previously disenfranchised of their land are now engaging in the activity of co-management of natural resources with a view to beneficiation of the wider community. In this case, we analyse early historical data in expansive learning and new activity formation, to probe how communities navigate power relations in order to establish conditions for cognitive justice in change laboratory contexts where new activity formation for co-management becomes possible (case: award.org.za).

Case 2: A case of communal farming activity in the south eastern part of South Africa in the Eastern Cape Province, Nkonkombe Municipality where communities previously disenfranchised of their land and later forced into communal farming under Bantustan state regulation are now developing a more democratically constituted form of communal food gardening under harsh conditions of drought and loss of technology capacity for supply of water to food gardens. This leaves elderly people with the difficult activity of carrying buckets of water to drums to provide water for their gardens, and food for their families. Rainwater harvesting and conservation (RWH&C) as alternative water management activity, involving a multi-stakeholder learning network, is being developed by the Lloyd Village community via CHAT expansive learning change laboratory workshops (case: amanziforfood.co.za).

In both cases, we firstly describe the history of the object of commoning activity (co-management in Case 1, and communal RWH&C in Case 2), the activity systems involved, contradictions emerging at the interface of interactiing activity systems, change laboratories, networked and expansive learning processes, and emerging evidence of agency expressions and transformative agency (Engeström and Sannino, 2010).

Secondly, we deepen the analysis of these processes of expansive learning and agency formation using lenses of decolonization and cognitive justice and we reflect critically on how communities navigate power relations in order to engage in transformative activity oriented towards sustainability, the common good, and a re-claiming of the commons. These power relations, as our data shows, are complex, multi-layered, deeply historically and culturally imbued, and are extremely difficult to navigate in modern conditions. Yet people involved in the expansive learning processes do this, showing a willingness to traverse colonially instituted and other oppressive boundaries, in attempts to build new human activity that is beneficial to themselves, others and the common good. Two extracts from the data show but some of the contours of these dynamics:

"Equity partnerships in the co-management agreements must provide landowners with shareholding in the businesses, jobs and opportunities" (Case 1: Co-management agreement conditions document drawn up by previously disadvantaged communities).

"We will also participate in the trainings because farmers must not know more than us" (Case 2: Extension Officer -male, Personal Communication, July 15, 2014).

While the focus of our analysis is on local sustainability-oriented and commonality building activities, the analysis presented here has wider resonance as re-claiming the commons is not only a matter of concern for local rural communities in the global South who have been disenfranchised, but is rather a matter of concern for people across the planet who share common good resources such as clean air, water and the planet itself.

Dialectics of expansion and contraction: The emergence of a rural credit cooperative in the southwest of Paraná State, Brazil

Manoel Flores Lesama, Federal University of Paraná, Brazil; Antonio Carlos Picinatto, Federal University of Paraná, Brazil; and Marco A. Pereira Querol, Federal University of Sergipe, Brazil

Sustainable agriculture faces the challenge of how to finance its operations. The study aims at analyzing the learning processes and the agency of farmers and rural advisors during the creation and development of a cooperative of rural credit for Sustainable Agriculture. Learning is not linear, but both expansive and contractive. Moreover, the production of social organizational structures to support sustainable practices, such as cooperatives and associations, involve agency of local actors, taking actions to transform their local activities.

Methodology

The developmental trajectory of the emergence and development of a rural credit cooperative is investigated through a historical analysis. The unit of analysis is a network of functionally connected activity systems. Historical events, understood here as actions, are selected using the concept of critical events, which are events that change the elements of an activity system. Here, we are particularly interested in the events related to the creation of the cooperatives that support farms towards more sustainable production in the Southwest region of Paraná State, Brazil. A narrative is produced by organizing the historical events in a chronological order. The narrative is then analyzed using the model of the cycle of expansive learning, in which developmental phases are identified by observing qualitative changes in the structure of an activity.

The case

In 1966, in order to support alternative more sustainable forms of agricultural production, a group of small farmers from the Southwest region of Paraná, with the support of priests from Belgium, created an association of farmers called ASSESSOAR. The association promoted solutions to the challenges faced by farmers so that they could produce an *alternative agriculture*. Alternative refers to the adoption of practices and technologies that preserve the environment. The function of agriculture was not only production of commodities, but also conservation of natural resources and maintenance of local communities.

In order to support more sustainable production, the participants of ASSESSOAR, using financial resources from European NGOs, created a Rotating Credit Fund. The fund was successful in financing small farmers who were interested in producing more sustainably. However, the volume of credit was an important limitation to expand the credit to a larger number of farmers. Moreover, a group of rural advisors who did not agree with the *modern agricultural model* created a new cooperative of rural advisors called COOPERIGUAÇU.

In 1995, social movements together with trade unions and representatives of Landless Workers Movement started a series of protests requesting policies for family farmers. These sets of protests from the social movement called *Grito da Terra* (Cry from the Land) led to the creation in 1996 of a new rural credit line exclusive for family farmers, a line called PRONAF – Custeio.

ASSESSOAR and COOPERIGUAÇU supported the creation of cooperatives of rural credit in Paraná State, forming the cooperative system of credit called CRESOL. Despite being directed to small farmers, PRONAF-Custeio followed the old logic and principles of the model of credit created during the dictatorship period – originally created to finance *modern* inputs such as pesticides and chemical fertilizers. Therefore, the credit became a way to finance technologies aimed basically at increasing production and productivity.

To sum up, the new cooperative CRESOL and the rural credit line PRONAF –Custeio, which were solutions that were aimed at supporting sustainable production, soon became instruments for conventional modern agriculture.

Preliminary findings

Two findings are highlighted on the basis of a preliminary analysis of the case. First, the study shows that the cooperatives ASSESSOAR, COOPERIGUAÇU and CRESOL were attempts at supporting an alternative model of more sustainable agriculture. They were outcomes of the initiatives of local farmers, local rural advisors, and European priests. Their actions were motivated by the negative consequences of the conventional model of agriculture. They created cooperatives and associations to overcome the challenges faced in small farms.

Second, the study shows that the long-term trajectory of collective learning in this case is neither linear nor exclusively expansive. The ASSESSOAR and COOPERIGUAÇU were important expansions towards making sustainable agricultural production viable in small farms. However, the tentative effort to expand the volume of credit available to small farms through the creation of the new cooperative CRESOL and PRONAF-Custeio increased the volume of money, but also changed the object of the financing activity. The object changed from financing environmentally and socially sustainable food production to highly productive and highly profitable standardized commodity production. This change is interpreted as a qualitative contraction of the object. Although there has been discourse in CRESOL about the importance of financing sustainable agriculture, the practices show that the credit has been directed only towards conventional forms of agriculture.

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Negotiating Academic Communities: Narratives of Life-long Learners

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Abstract: We bring together three case studies in computer science and engineering which were launched for the same purpose: to understand what participants – students, high-school teachers, and university teachers – considered themselves to be significant in their pursuit of professional growth and what empowered and disempowered them. All three studies use narrative methods, although in different ways. The studies share two findings: (a) participants were engaged in processes of becoming or being life-long learners, and (b) the importance of community in their narratives.

Keywords: computer science, narrative methods, community, life-long learning

Introduction

Computer Science (CS) and engineering face challenges due to rapid technological changes. Teachers need not only to keep up with these changes but must also be able to teach the changing material. Students have to develop the ability and propensity to constantly learn, adopt and adapt changes. In this symposium we bring together three case studies in computer science and engineering which were undertaken for the same purpose: to understand what participants – students, high-school teachers, and university teachers – considered to be significant in their pursuit of professional growth and what empowered and disempowered them.

All three studies used narrative methods. Specifically, in the first study, Dziallas interviewed American CS and engineering students in a learner-centered engineering program about their learning processes over the course of their life. In the second study, Fincher followed CS higher education faculty from various countries for a year, asking them to fill out a diary one day every month, capturing details of their daily work. In the third study, Ben-David Kolikant and Brandes asked CS teachers who participated in leading teachers courses to write their professional biographies. These methods differ. Fincher's diaries are written in present tense and tell the story of single days, reflecting what participants saw as being important at that time, while both Dziallas and Ben-David Kolikant and Brandes used retrospective biographical approaches, albeit differently.

Nevertheless, the findings of these studies are similar in two major aspects. First, participants were engaged in processes of becoming or being life-long learners. In all studies the desire to excel for self-realization was a prominent drive. Students and teachers alike developed their own rule systems and paved their own ways. In both Fincher's and Ben-David Kolikant's work, university and high-school teachers respectively reported dealing with time management and logistics, yet spending valuable time planning new projects, finding new learning opportunities – and moreover, they expressed positive emotions towards these challenges. In Dziallas' study the students had to adjust to an environment specifically designed to develop these lifelong learning skills.

Second, the importance of community permeates these narratives, albeit with a different expression in each. In Dziallas' study, students develop lifelong learning skills at a college where they live on-campus for all four years of their undergraduate education in an immersive community. Ben-David Kolikant and Brandes found that participants in the leading teacher program valued the sense of community the program gave, to be with "peculiar creatures" like themselves. And in Fincher's diary study, participants negotiated relationships within local and disciplinary communities.

This symposium, hence, sheds light on the processes of becoming and being life-long learners, and the difficulties they entail. It raises questions regarding the role of one's actual and designated identity in (life-long) learning. (Sfard and Prusak, 2005) In Dziallas' study, students' designated identities, the wish to become part of a community, brought about substantial learning. However, in the other two studies concerning professionals' learning, it was their actual identity, that of life-long learners, which brought about learning. The community surrounding them was not a designated one, it was an actual one. Indeed, the professionals experienced their community as an essential resource to sustain life-long learning; in all case studies, it is the community which is the basis of participants' sense of empowerment. This symposium also highlights the benefits of narrative approaches, their diversity and richness in exploring professional development and growth.

Students' positioning in life stories of learning experiences

Sebastian Dziallas

Introduction and context

The goal of this study was to explore how classroom and campus community influence student learning; how students position themselves in them; and how they make sense of their own experiences over time.

Phil Hammack argues that we construct narratives to make sense of our experiences by integrating stories of culture with our daily experiences. These stories of culture are scripts available to members of a particular group (such as students at a specific institution) – they are master narratives (Hammack, 2008). Students position themselves against these scripts. Of course, they are specific to institution and context – they can't simply be transferred. But the stories and positions we identified may provide opportunities for other institutions to draw upon as they look for ways to help their students develop lifelong learning skills.

In this work, then, we draw on interviews from a preliminary study with a dozen students at Olin College. Olin College is a small undergraduate institution in the United States that was founded in response to multiple calls for change in engineering education (National Academy of Engineering, 2005). The overall learning environment at the college was designed to be deliberately disruptive: all of the 350 students live on campus for the duration of their degree program and the curriculum is largely project-based with much of students' work grounded in real world and interdisciplinary contexts. In a paper describing the initial curriculum at the college, the faculty called for it to "motivate students and help them to cultivate a lifelong love of learning." (Somerville et al., 2005) In a previous effort, we explored the role of the curriculum in shaping students' learning experiences (Dziallas & Fincher, 2014). Now, we are interested in how the campus community and students' view of themselves in it shape their development as lifelong learners.

Methodology

The concept of positioning theory is about "how people use words (and discourse of all types) to locate themselves and others." (Moghaddam & Harré, 2010) Yamakawa, Forman, and Ansell use positioning theory to explore how students and teacher position themselves in the context of a third grade mathematics classroom. They consider individual speech events – for example students discussing the solution to an assignment with the teacher – in classroom discourse. They then describe implications of this positioning on students' identity construction. This discourse-centric perspective leads them to adopt a social stance on identity, which, they argue, is "temporary, changeable, and unstable in nature." (Yamakawa, Forman, & Ansell, 2009)

We employ a similar approach in this work, but rely on individual life story interviews which were drawn from a protocol originally developed by Dan McAdams (McAdams, 1997) to focus on students' learning experiences. As part of this approach, we adopt a perspective of unity and coherence in the self, as it is common in life story approaches, allowing us to trace students' wider learning trajectories and to hear echoes of past experiences. Life story approaches are grounded in a tripartite model of personality consisting of dispositional traits, personal concerns, and narrative identity. In this model, narrative identity consists of the life story that we, as adults, "[continue] to author and revise over time to make sense, for [ourselves] and others, of [our] own life in time." (McAdams, 1995) It is an internalized and continually evolving story of who we are.

Findings

Community and confidence

One of the themes we originally identified in the interviews was an academic dislocation upon entering college "that reinforces fundamentally different values of what it means to be an engineer" from students' previous, largely grade-driven, experience in high school (Dziallas & Fincher, 2014).

> First semester was getting used to Olin and is interesting, because it is the culture shock. You are surrounded by the same 300 people, and all these people are doing amazing projects, and you just feel like, especially freshman year, you feel like you aren't good enough. [Natalie Lee]

Here, Natalie (we use pseudonyms throughout) is positioning herself in relation to others in the community as somebody who, having just arrived on campus, isn't initially "good enough" despite her previous academic achievements and acceptance at Olin with its competitive admission process. In fact, this sense appears to be directly connected to her perception of others within the community. However, through opportunities afforded to her in both the local campus and wider academic community, her confidence grew.

I was [a teaching assistant for] a class and people actually wanted my help, and I was actually useful. I felt like I could actually share my information. Olin gave me this new sense of confidence that I didn't really ever have before. [Natalie Lee]

This newfound "sense of confidence" permeated our conversations with students. For many of them, it allowed them to reposition themselves in the community. This transformation in students' perspectives of themselves and their learning appears to be driven by a change in what it means to study engineering in this new context: in terms of what kind of knowledge "counts" as engineering knowledge (Stevens, O'Connor, Garrison, Jocuns, & Amos, 2008), but also in terms of what kind of learning is supported and valued by the community at the institution. For Natalie, this shift manifested itself in her growing more confident in listening to her internal voice and taking a course she was passionate about.

I was planning on taking some sort of bio engineering class … and then I realised that there is this other class I wanted to take at the same time. I made the decision to drop the bio classes and take "Teaching and Learning" instead. Which was actually a really hard decision to make, ... but I did it anyway. It was the best decision I have made so far. [Natalie Lee]

Faculty support

Another theme we identified involves the community encouraging discussions of classroom experiences. For example, Samuel positions himself here as somebody willing to engage with and improve his education. And to his surprise, he discovers that others have positioned themselves similarly in this new community.

So, first off, the ability to look at [a course] and say, "Here's some concrete things that I don't like about this experience" was amazing. The second was being around people, students in this case, who were similarly engaged in this class and in their education. That I could talk with them about what they didn't like and come to a level of understanding where we could start thinking of possible solutions was further incredible. [Samuel Cline]

This kind of engagement extends to faculty members as well.

And lastly, that I was at a place where we could talk to a professor for multiple hours on a weekend – one of the busier professors – for multiple hours on a weekend... [Samuel Cline]

Another student was even more explicit about the close faculty-student relationship she found at Olin.

… there was a shift from looking at professors as guiding figures, to looking at professors as colleagues. People who want to know about me, as much as I want to know about them. They want to know about what I know, as well as I know want to know what they know. [Susana Clinton]

This shift affected her own approach to learning.

I decided that it was more important to develop good relationships with the faculty, than to necessarily understand everything that they're saying in class. So while I do still attempt to understand, it's not super important that I understand as much as I understand how to learn how to understand. [Susana Clinton]

Susana positions herself as seeking "good relationships" with professors at Olin. However, in the context of the Olin community, this desire is not driven by a focus on extrinsic metrics, such as grades. She is instead looking to "learn how to understand" for herself. Indeed, in a shift from the previous model, her conception of learning appears to be linked to interactions with people in the community around her, rather than test scores.

Discussion

If learning is conceptualized as participation, then what is learned are the norms and practices of a community (Sfard, 1998). In schools, students and teachers participate in collective work to construct, maintain, or alter the cultural and historical practices of their classroom community. (Yamakawa et al., 2009)

This perspective emphasizes the importance of community for learning. We have characterized students' conceptions of a learning environment that was specifically designed to foster lifelong learning and discovered that these conceptions include the campus community. Students repositioned themselves within this community over time which was an important aspect of becoming life-long learners. We saw commonalities of developing confidence and intrinsic motivation in their stories (similar to, for example, the concept of self-authorship). As students enter this new part of their learning journey, they describe a process of becoming empowered, feeling more confident, and adopting positions more equal to faculty. Indeed, changing educational practices in the classroom to foster lifelong learning skills alone may not be sufficient. The positions faculty and students adopt with regard to each other appear to be a central part in the development of students' conception of their learning. We contend that the community at Olin encourages this kind of behavior and that its structure influences the possible positions its members adopt – to study, to engineering, and to lifelong learning.

Non-storied narrative: Community in academic diaries

Sally Fincher

Most academics experience, if not inhabit, two communities. One is the local community of their University context, the other is as cosmopolitan researchers, reaching out to a community of collaborators and peers in other institutions. This is a well-observed phenomenon, first framed by Robert Merton who distinguished two role orientations and introduced the terms "local" and "cosmopolitan" in this way:

> The localite largely confines his interests to this community. He is preoccupied with local problems, to the virtual exclusion of the national and international scene. He is strictly speaking, parochial." whilst the cosmopolitan has some interest in the local community "he is also oriented significantly to the world outside and regards himself as an integral part of that world. (Merton, 1957, p. 447)

Merton's student, Alvin Gouldner, took this distinction into a study of 125 faculty members from a mid-range US university he calls "co-op college" (Gouldner, 1957, 1958). In this explicitly educational context, he defined his two latent organisational types like this:

> Cosmopolitans: those low on loyalty to the employing organization, high on commitment to specialized role skills, and likely to use an outer reference group orientation.
> Locals: those high on loyalty to the employing organization, low on commitment to specialised role skills, and likely to use an inner reference group orientation. (Gouldner, 1957, p. 290)

Gouldner defines these as "latent" rather than "manifest" types because people with ostensibly identical roles ("associate professor" or "senior lecturer") may, in fact, have different orientations. Nevertheless, it is clear that researchers are more likely to have a cosmopolitan orientation: they have an external community from where they draw validation and specialised disciplinary skills. Teachers, on the other hand, are more likely to have an orientation to local context and constraints, and draw validation from the institutional community. In education, these distinctions have been widely drawn on to characterise academics' activity (Baker & Zey-Ferrell, 1984), and to explore the implications for the amount and balance of academic work, including issues of status and reward (Grimes and Berger, 1970) (Tuma and Grimes, 1981). However, in this work, rather than applying these categories as theoretical distinctions, we were more interested to examine how these communities were formed and experienced. In this, we looked to the minutiae of academic life, as recorded in academic diaries.

The corpus

The Share Project (SP) ran from 2008-2012 and aimed to gain insight into how educators share teaching practice; how they represent it; and how, when and with what evidence they change their practice (http://www.sharingpractice.ac.uk). The project comprised several inter-related investigations and used narrative both as a medium with regard to representing practice and as a methodology in research studies. In investigating teachers' practice, SP undertook four distinctly separate narrative enquiries (Fincher, 2012). One of these, modelled on Mass Observation (MO & Harrisson, 1943) asked academics to keep a diary on the 15th of every month between September 2010 and August 2011.

In using a diary elicitation, we were anxious to find out what was significant in academics' lives - not what someone else thought should be significant. The solicitation was explicit: "We want you to tell us what you really do. We're interested in detail and nuance, in the gaps between what is supposed to happen and what does happen, between staff and student, between institution and individual."

The texture of academic lives is distinctively different depending on their disciplinary orientation. For simple example, Humanities scholars tend to work alone, or in very small teams, with modest grant income; Science academics tend to work in labs, often in substantial research groups, on substantially funded projects. This paper eliminates the variance of discipline by reporting a study of computer science academics that draws on a subset of 82 diarists from 389: this selected corpus comprises 575 entries.

Method

The day-survey diaries have an overwhelming emphasis on the quotidian, the ordinary, the matter-of-fact. This collection allows us an ant's-eye view of academic life, from the small, daily interactions that the diarists report, either as commonplace, or as unusual. Rather than seek "themes" we coded for concrete action and activities and systematically extracted details in several groups:

1. *Interactions and activities*: in this category we noted personal interactions that might indicate involvement in personal and professional networks. We noted conversations with Heads of School, IT departments, professional colleagues, etc. We also included interactions in regard to professional activities more broadly meetings with research students, attending conferences, work on grant proposals, etc. These latter items helped form a more complete snapshot of the kinds of things a diarist is doing. Description of meetings over food (lunch, coffee etc.) were separately noted.

2. *Representations of practice and artefacts of practice*. This category included references to lecture slides or assessment activities, as well as implicit use of representations (e.g. at meetings discussing curricular revisions).

3. *Change Examples*. We extracted all examples of change in teaching practice in two groups. One group contained description of changes in practice and preparation habits, the other was composed of references to student-driven change, where the diarist adjusted their delivery or materials in response to student feedback or observation.

Academic community

In the diaries most often (although not universally) both of Gouldner's community constructions were evident, and often illuminated when they come into conflict. One way in which conflict occurs is when boundaries are breached, and we saw several variations of this (Cohen, 1985). Sometimes the boundaries are internal, where institutional priorities conflict with departmental work:

> Looking back, I don't think I did a single stitch of actual computer science work or even thought about the process of actually teaching computer science. All of today was strategizing about outreach or administration of programs. [264, June]

More commonly, however, the diarists identify the conflict of local and cosmopolitan community in terms of finding time and space to do justice to the work of both:

> Snuck a few minutes to read reviews of our CHI submission. It's a new community for us and I found the reviews really informative … It's nice to think about research, even if only for a few minutes in the day. [47, Nov]

> Managed to get some of the research work completed. It is a struggle to balance the good teaching with good research [73, Nov]

> Having spent the last two days reviewing student project reports, it was good to be able to get back to revising a research paper this morning. I have now sent off the revision to my co-author in Canada. [75, Sep]

As well as these expected constructions, in narrowing our focus to a single discipline we were struck by the quality of activities and interactions that related specifically to these academics' disciplinary orientation, as something separate from their engagement with institutional and research communities. The field and subject matter of computing is driven by fast-moving technological advances, and is in constant flux. Student expectation is conditioned by current devices, and there is no sense in which the same lectures can be delivered year-on-year, as in subjects with less volatile material. Most often this was mentioned regard to the currency (and credibility) of teaching material. Sometimes references are immediate and personal, a matter of knowledge and challenge:

> Beej changed all of his examples to take advantage of IPv6 networking routines … My examples (and notes) will need to be almost completely rewritten because the technology changed. [50, Sep]
>
> I teach computer science. Today will be spent trying to learn a programming language that I may be called on to teach in the future. Won't spend a lot of time on it, but I should get started. A few months ago, I started wondering just how many programming languages I have used, or at least studied in my 40 years in the field. It was 14. After 14 languages, number 15 won't be hard, I think. [45, Aug]
>
> Also took a look at some material on ASP.NET MVC as I'm due to teach this to postgrads soon and I'd better know something about it by then!" [38, Oct]

Sometimes the reference is more general, linked to departmental concerns and local community:

> We discuss plans for the revised Masters' program. It seems our programs need constant revision to keep up with industry expectations." [60, Nov]

We characterised this consistent external reference as a "third community". Diarists assumed on-going engagement with current technology as part of their pedagogic responsibility to their local community, not only in its impacts on their personal practice, but also in regard to students' development.

> I had a chat with people in my department who were playing with the latest iPad technology and discussing how they were incorporating it into their multimedia lectures. [28, Jan]
>
> I really like to use practical tools in my courses. I think it's important for computing professionals to develop skills in finding their way through new technology. The challenge is that requires a significant time investment in not just learning the tools, but also updating assignments, lab description, and installation instructions. [116, Oct]

Implications

Diaries (and quotations from diaries) are, by their nature, unremarkable. But they are also revealing in their record of the routine; these narrative fragments expose the everyday dance that academics tread, reconciling the demands of different communities, and different community pressures, that inform their professional lives. The "third community" that the computer science diaries expose suggests a different sort of academic engagement, one that sits between Merton and Gouldner's local and cosmopolitan constructs. It is distinctive because "membership" of the third community crosses boundaries, requiring that materials and methods from an external reference group are not simply used to validate external standing (as is the case with cosmopolitan research) but must be imported and instantiated to maintain standing in the internal, local, community (in teaching). The daily-constructed stories of *actual identity* (Sfard and Prusak, 2005) recorded in the diaries might indicate that professional academic identity in computer science is supported by a powerful, engagement with life-long learning.

Acknowledgements

The need of community of equals at times of changes: The narratives of Israeli CS leading teachers
Yifat Ben-David Kolikant and Ofra Brandes

Supporting and nurturing life-long learning skills and disposition among teachers is an important and challenging task in this era. Teachers need these skills to rapidly adjust to frequent and substantial changes in curricula and policy (Gilbert, 2006). Many models of teacher growth assume that the content knowledge is stable (e.g., Berliner, 2001) and put the emphasis on what Shulman termed as pedagogical content knowledge (Shulman, 1986; 1987). CS education is characterized by extreme instability of the curricula and teaching methods (Roberts, 2004) and as such it can serve as, metaphorically, a mirror into the future school reality of rapid changes.

Here we report on a study conducted in Israel at a time of a dramatic change. CS has been an elective course in Israeli high schools for many years. In 2008 the Israeli high-school CS curricula moved from procedural programming to object-oriented programming (OOP). CS teachers had to teach a paradigm they did not learn in the university and did not use for their own programming projects. Teaching materials (textbooks, teacher guides,

laboratory sessions, and so forth) were developed by groups (of teachers and researchers) appointed by the ministry of education. Yet, the dissemination both of the new content knowledge and of the "best" ways to teach it were, and still are, a challenging task.

The concept of "CS leading teachers" course was developed to address this challenge. The courses are annual and involve a small group of teachers with good teaching reputations. The underlying assumption is that these teachers can serve as agents of change in their field. The courses have been run by Machshava, the Israeli CS national teacher center. Each year is devoted to a certain topic and contains a component of participants' work for the wider community of CS teachers, for example, the preparation of laboratory assignments and exercises. Specifically, in 2008, when the Israeli high-school CS curricula moved from procedural programming to OOP, these teachers were taught OOP in the course. In parallel, they taught it in their classroom for the first time. They were also asked to conduct workshops on OOP for fellow teachers. The course supported these activities by providing time and a framework for discussing how to teach the new content in their own practice and to fellow teachers.

The study reported here is a part of a bigger project launched in order to understand the professional growth of these teachers. As part of this, we solicited the professional narratives of these teachers as well as their professional self-perceptions (Van Driel et al, 2001). To this end, we asked 12 teachers who participated in these courses to write their "professional biographies". Participants included all the teachers who participated in 2008 and who conducted a workshop for fellow teachers. All participants also participated in the course at least three more times, in subsequent years. The instructions were to write 2-3 pages with the guidelines: "don't provide us with a list of formal training opportunities; we are interested in a description of important junctions, significant decisions and deeds as well as your self-perceptions as a teacher."

It seems that these teachers are life-long learners. Specifically, several characteristics emerged in the teachers' description of their professional path. All the participants defined themselves as pioneers, or, using the words of one of them as "jumping into deep, cold water". Not only were they accustomed to the rapid changes, they were also looking forward to new programs and projects, being eager to challenge themselves. Seven teachers (58%) described their professional growth using the words "in parallel" or "at the same time", emphasizing that they were never content with "just teaching", but rather were always engaged in additional, self-motivated professional activities, such as studying in the universities, taking (or giving) professional development courses, initiating a new track in school, working in programming in the industry, and developing teaching materials and books. The majority (75%) mentioned that requirement to teach a new paradigm meant that their content knowledge (let alone pedagogical content knowledge) was often far from perfect, however they embraced the fragility: "never mind. If I made a mistake, I'll fix it in the next lesson". The main difficulty they experienced was loneliness, having to cope with innovations by themselves. Some participants mentioned creativity as an important feature, having to develop materials for themselves.

Two thirds of the participants mentioned the course as a significant step in their professional growth, all of them justified it with the opportunity to form a community, a tighter collaborative relationship with peers with the similar propensity of embracing change and challenge. These relationships were valuable in the contexts of teaching new programs, they helped them to better cope with their fragile (pedagogical) content knowledge, consulting and exchanging ideas, tips, and materials.

Five participants (42%) mentioned that the course enabled them to extend their professional actions beyond the walls of their classrooms, especially to help peers, directly or indirectly (e.g., by producing teaching materials), and make an impact on the CSE community by serving on committees and attending conferences. Most of the teachers valued the course because of the community it had helped them to form and not, for example, because of the exposure to new content and the encounter with University academics. This result suggests that although these expert teachers were far from being novices, and certainly were capable of learning by themselves, they valued the community, which in turn suggests that what life-long learners in this domain need is a continuous opportunity to have a community of equals, where they can elaborate difficulties emerging from their fragile content knowledge as well as share and exchange pedagogical ideas.

The fact that only 42% of the teachers mentioned the course as preparing them to be agents of change in the bigger community of computer science teachers aligns with a previous study on an earlier course of CS leading teachers, that of 2004, in which participants' initial self-perception was that of knowledge consumers, interested merely in their own teaching, rather than that of contributors to the greater community (Ben-David Kolikant and Pollack, 2004). We believe that a focus on become change agents can and should be nurtured throughout the course. For example, the design of the course by Ben-David Kolikant and Pollack (2004) supported such a change. More work is needed in order to pursue ways to recruit these teachers' enthusiasm towards challenge and change for the benefits of the wider community of CS teachers.

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Future Learning Spaces for Learning Communities: New Directions and Conceptual Frameworks

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Abstract: This symposium presents our efforts to reconceptualize learning spaces from their traditional notions as bound and immutable to a view in which the physical and social boundaries are flexible and dynamically connected to the learning itself. We present the work from five international research centers that consider space as a multi-dimensional mediational tool that shapes, and is shaped by, the learning communities who use them. In each case, researchers will present their innovative spaces along with the learning community frameworks they use to describe and design them. Each study demonstrates specific insights regarding how to conceptualize and design Future Learning Spaces for Learning Communities.

Keywords: design, future learning spaces, learning communities, sociocultural

The various arrangements among humans, computers, and space within a particular classroom context impact the dynamics of the learning environments created. (Bielaczyc, 2006, p. 304)

The classroom is significant not just as a material location in which education research is located..., but also as a conceived or imagined space—an imagined geography of a particular kind. (Leander, Phillips, & Taylor, 2010, p. 331)

Introduction

This symposium addresses the conference theme of *Transforming Learning, Empowering Learners* by uniting two theoretical issues of vital interest in the learning sciences: Future Learning Spaces (FLSs) and Learning Communities (LCs). The timeliness of this conversation is critical given the current state of educational reforms around the globe whereby large and expensive infrastructure decisions are being made such as in renovating schools and classrooms. History has taught us that these reforms often fail to impact learning because they are based on "more of the same" instructionist pedagogies (Cuban, 2001; Scardamalia & Bereiter, 2006) or fanciful "futurist" visions of physical learning environments that are not connected to any specific pedagogical principle. While there is often a great deal of hype in popular media about new educational architectures (1), such ideas frequently overvalue the role of space without giving deep consideration to the principles of learning underlying these projects. Coherent frameworks that are based on principles derived from the learning sciences are needed to guide the construction and use of new spaces so they are used in pedagogically meaningful ways (Sawyer, 2014a).

Our combined projects can offer important contributions to the exciting and ongoing LC research within the learning sciences. As LC thinking evolves, there are new possibilities for what can be done by considering the spaces where they are situated. For example, new technologies that are reported upon in this symposium allow for distant knowledge building communities to learn from each other's collective idea threads (see Zhang & Chen). Embedded "Wallscopes" allow students to carefully observe life cycles of multiple habitats within the walls of one classroom (see Slotta, Cober, Acosta, & Moher). Pod-like furnishings and arrangements in undergraduate physics classrooms promote active learning and community-based knowledge (see Charles, Whittaker, & Lenton). Flexible walls, easily combinable furniture, and embedded screens allow for opportunistic collaboration within an emergent-design (see Ben-Zvi, Hod, Kali, & Weiss). Finally, open technology-enabled collaborative spaces allow multiple LCs to enact their practices (see Rook, McDonald, Choi, & Tietjen). Together, these projects show how LCs can be refined by considering the way space constrain or give new opportunities to certain kinds of activities and practices.

As there is greater public acceptance around the need to reshape educational spaces (The New York Times, 2013), the learning sciences has an increasingly challenging role of translating its findings to the public sphere. By deeply studying how learning communities interact with their physical environments, we hope to offer a coherent vision to guide reform, which includes the physical and locational aspects of learning. While this symposium is a small step forward in this disciplinary endeavor, it is invariably important to the goal of transforming learning and empowering learners. In the following sections, we provide a background to these issues in learning sciences research, laying the theoretical grounds to consider the five innovations in this symposium.

The future of learning and education

It is important to interpret the emergence of the LC approach and FLSs within the present cultural and historical context. Whereas knowledge and skill acquisition were once vital for economic growth in the industrial era, today's society demands that its participants have more generic problem solving and communication skills, including the ability to find and learn from various media, solve ill-structured problems and collaborate with peers. Recent advances in technologies such as smartphones and online communities have significantly extended opportunities for the development of these skills, increasingly questioning the relevance of traditional schooling (Sawyer, 2014b). It is becoming ever more important for education to customize learning, make use of diverse knowledge sources, specialize assessment, and provide opportunities for students to learn-by-doing. These new demands in an emergent innovation society have led to incompatibilities with the traditional educational system, such that many consider the current disruptions as revolutionary (Collins & Halverson, 2009).

While the learning and education that will take place in the future is still a matter of some conjecture, learning sciences research on FLSs and LCs are closely connected with this developing trend, and can help guide the complex transition through a rigorously advanced body of knowledge. Whereas classrooms have traditionally been seen as immutable containers for the transmission of knowledge, today issues of space have entered learning sciences research to support the new demands on education and learning. Likewise, innovations in educational thinking over the past several decades have led researchers and practitioners to develop coherent classroom designs that capture the large ideas of a new theory of learning (Brown & Campione, 1994). Together, FLSs and LCs offer two key interrelated perspectives that stand at the heart of the disruptions in education and which have the potential to transform learning and empower learners for the 21st century innovation society (Facer, 2014).

Learning communities

One of the useful ways that learning scientists have approached the problem of re-conceiving and re-designing education has been by adopting sociocultural perspectives of learning. Rooted in Vygotskian thought, this perspective views learning as mediated by cultural and historical tools that individuals internalize as they are socialized throughout their lifespan (Wertsch, 2007). Educational researchers have extended this view by considering learning as a matter of transformational participation in certain ways of knowing (Rogoff, 1994), such as in the practices or discourse of particular communities (Lave & Wenger, 1991). In this perspective, the design of educational content and learning environments moves beyond the domain of transmitted content.

LCs, which are a translation of these theoretical ideas into practice (Bielaczyc & Collins, 1999), have been a long-standing interest of the learning sciences (2). Early studies advocated LC models as a means of transforming classrooms to be relevant for contemporary society (e.g., Brown & Campione, 1994; Scardamalia & Bereiter, 2006). In addition to establishing a culture of learning that emphasized collective knowledge building, these LC models valued contributions of diverse members, advanced collective knowledge, emphasized learning how to learn, and developed mechanisms for sharing the community's knowledge (Bielaczyc & Collins, 1999). Based on the LCs framework and spurred by emerging collaborative technologies, the past 20 years has seen a

proliferation of exciting ideas and models. These have come about within various educational settings like schools (e.g., Herrenkohl & Mertl, 2010; Hogan & Corey, 2001), universities (Fischer, Rohde, & Wulf, 2007; Hod & Ben-Zvi, 2014), professional settings (Stoll, Bolam, McMahon, Wallace, & Thomas, 2006), informal settings (3), and more recently online (e.g., Kafai & Fields, 2013; Kidron & Kali, 2015; Resnick et al., 2009).

Learning spaces

Along with new conceptions of pedagogies, activities, and assessment practices that have come with LCs, space has gained relevance as a mediator of social configurations and interactions for students' transformation of participation (Jordan & Henderson, 1995). One line of research that has emerged is the exploration of how physical arrangements are designed meaningfully to foster students' trajectories from vernacular discourses and peripheral participation to authentic discourse and practices (Roth et al, 1999).

This increased focus on socio-materiality has come as part of a growing recognition that space is only one among the ubiquitous mediating structures that support the development and distribution of cognition in complex relationships (Pea, 1993). Instead of treating learners and their contexts separately, research on learning spaces emphasizes space within the other situationally related tools such as activity, social or epistemic norms, assessment, and learning trajectories. This integrated view of space and the mutual fertilization of mediators within learning ecologies is one of the greatest opportunities and challenges of coming to theorize the role of space in learning.

An additional factor is the concept of learning space itself. While space is often considered as the physical or locational aspects of a room (e.g., Moher et al., 2015), there is also recognition that space is socially constructed. Meaning, space can be seen as not just a material object in a learning environment, but as an "imagined geography" (Leander, et al., 2010, p. 331). The idea behind a "fun space" or even "future learning space" are examples of the type of ongoing negotiation around this idea. New mobilities of learning due to the changing social spaces afforded by new technologies make such conceptions increasingly relevant (Leander, et al., 2010).

Symposium structure

To put into practice some of the common ideas that the contributors seek to present, this symposium will be organized as an interactive poster session so that participants can be active and develop collective knowledge (e.g., Kali et al., 2015). The format of the session will include an introduction, led by the session co-chairs, which describes our framework to consider five diverse, international lines of research on FLSs for LCs. Following this, contributors will briefly describe their research to the participants, who will engage in interactive discussions around each poster. The co-discussants will then provide their perspectives, which will be followed by a moderated whole group discussion. To support this session, we will create a shared online space, consisting of linked Google documents where participants will add and discuss their ideas.

Interconnecting the knowledge spaces of different communities for sustained knowledge building

Jianwei Zhang and Mei-Hwa Chen

Real-world knowledge-creating communities achieve productivity through sustained inquiry and progressive discourse by which ideas are continually developed, refined, and built upon, giving rise to more advanced conceptualizations and deeper goals (Sawyer, 2007). Such efforts are further supported by interactions across communities that work as an interconnected intellectual field (Csikszentmihalyi, 1999). Educational efforts to create LCs for knowledge building need to enable similar social and cognitive dynamics sustained over long periods of time (Engle, 2006). This research aims to create socio-technological spaces that connect the knowledge of different communities across classrooms and school years. Existing designs of collaboration across LCs rely on directly sharing the original online discussion space—a single layer sharing. However, doing so proves difficult (Laferrière et al., 2012), as it requires students to read the messy and lengthy discourse of others to understand their progress, causing high cognitive and collaboration load (Dillenbourg & Bétrancourt, 2006).

This project adopts a multilevel design to create a macro-level, cross-community knowledge space on the top of the discourse spaces of different local communities. The macro-level knowledge space is enabled by the platform of Connecting Idea Threads of Youth (CITY) developed on the basis of Idea Thread Mapper (ITM), a Web-based tool to trace conceptual trajectories in long-term online discourse (Chen et al., 2013). CITY interoperates with Knowledge Forum (Scardamalia & Bereiter, 2006) and other tools for collaborative discourse. As members in each community engage in sustained discourse in their protected online space, they review their unfolding idea threads, each of which consists of a set of idea contributions that address a shared theme or problem

(Zhang et al., 2007). Organizing distributed discourse entries into timeline-based idea threads helps to make the collective progress visible for reflection. Different communities then select and publish productive idea threads for cross-community sharing and build-on. Social interactions in CITY allow members to discover, follow, comment, cluster, and adopt the idea threads from different communities for mutual learning and dynamic idea contact.

A series of design-based studies have been conducted in Grade 3-6 classrooms (Zhang et al., 2013, 2014, 2015). Students engaging in collaborative reflection on unfolding idea threads were able to develop more connected and sustained discourse to address deepening issues. They further compared their own idea threads with those of other communities. Doing so helped them to better monitor their advances and weak areas, examine diverse perspectives, and adopt helpful questions, ideas, and inquiry resources to enrich their discourse.

Knowledge construction in the instrumented classroom: Supporting student investigations of their physical learning environment

James D. Slotta, Rebecca M. Quintana, Alisa Acosta and Tom Moher

We present research that leverages the physical classroom space to support a knowledge community in a classroom (e.g., Brown & Campione, 1996; Scardamalia & Bereiter, 2006). Our pedagogical model, known as Knowledge Community and Inquiry (KCI), builds on the foundation of knowledge communities, with an added major emphasis on scaffolded inquiry (Slotta & Linn, 2009). The present research was conducted within an instructional environment referred to as Embedded Phenomena for Inquiry Communities (EPIC; Slotta, Tissenbaum, Lui, & Zukowski 2012), where KCI was applied as a pedagogical model to develop a knowledge community for elementary students to investigate Embedded Phenomena. In EPIC classrooms, students work collaboratively (i.e., in small groups) and collectively, sharing information and solving problems. Interactions, including the exchange of data and theories, are carefully designed to support the growth of collective knowledge concerning the EP under investigation, as captured in various representational forms.

We employed the WallCology EP as the setting for whole-class inquiry, targeting life sciences topics of biodiversity and population ecologies (Moher et al, 2008). Over several weeks, 42 students from two grade-5/6 classes observed a digital ecosystem consisting of dynamic animations of insects and vegetation, visible through display monitors called "Wallscopes.". The ecosystem comprised four differentiated but interconnected habitats, one on each wall of the classroom, which varied in terms of environmental conditions (temperature, light and humidity). In our EPIC activity, students made observations about the morphologies and behaviors of organisms to determine their life cycle relationships. Constructing a representation of the lifecycles of any species was a challenging task; it was not always clear which organism belonged to which species (e.g., does the adult form of the "green bug" hatch from the white egg or blue egg?). It required careful observation (and maybe a bit of luck) for students to actually "see" life events like laying and hatching unfold. Additionally, since each monitor displayed a different habitat, students at one monitor see something different than students at another monitor, necessitating the sharing of observational data across various locations in the room, and over time.

The goal of EPIC is to create a more powerful means of sharing and working with such observations, by aggregating individual or group inquiry actions, encouraging teacher and students to attend to interesting patterns in the data, revealing gaps or conflicts in the collection, where more work is needed. The present paper analyzes the role of various visualizations of aggregate knowledge in supporting patterns of discourse within the community.

Designing active learning spaces to foster collaboration

Elizabeth S. Charles, Chris Whittaker, Kevin Lenton, and Michael Dugdale

Giving serious consideration to changing the instructional paradigm to more active student participation, universities and colleges have begun to invest in the redesign of learning spaces (e.g., Beichner et al., 2007; Dori & Belcher, 2004). Often referred to as active learning classrooms (ALCs), the architecture and furnishings intentionally use pod-like arrangements of 4-10 students to promote small group collaboration and multiple technologies for intra- and inter-group sharing. In doing so, ALCs call for the leveraging of grounding activities (Clark & Brennan, 1991) and devices that support the indexical referring made possible through shared perceptual spaces (Roschelle & Clancey, 1992). What is often overlooked in these scenarios of designing ALCs is the planning for the adoption of such pedagogical innovations by the users, instructors and students alike. In short, the move toward distributed authority systems puts new demands on students and instructors. It challenges students to take on a sense of collective responsibility (Scardamalia, 2002) and shared epistemic agency (Damşa,

Kirschner, Andriessen, Erkens & Sins, 2010), while requiring instructors to take up new pedagogical practices (Lasry, Charles & Whittaker, 2014).

Our contribution is based on the work of a cross-institutional researcher-practitioner team made up of learning scientists and physics instructors, at the college level in Quebec. Members of the team have been directly involved in designing and fostering the effective use of ALCs over a six year period. Using reflexive methodologies of action research and design-based research, the team has studied processes involved in adopting and effectively using ALCs to promote learning and change instructional practices. In particular, our action research has documented the development of LCs to support changing practices for instructors. Our current design research involves comparing the implications of the three primary models of ALCs within the college network. Differences between the ALCs models hinge on the types of perceptual spaces they provide the student groups (public vs. private, networked vs. singular, interactive vs. static) and the flexibility of the group configurations (fixed tables vs. flexible tables). These studies expand our understanding of how ALCs function and the roles student LCs play in determining how resources within these new spaces are used. For this session we will draw commonalities derived from these diverse case studies and suggest guidelines that support meaningful joint-activity mediated by the physical space and pedagogical commitment.

Design of a future learning space based on learning community principles
Dani Ben-Zvi, Yotam Hod, Yael Kali, and Patrice L.Tamar Weiss

We have been involved in a long-term design-based research study that has examined various aspects of our LC, situated within the Educational Technologies Graduate Program at the University of Haifa. The distinguishing principles of this LC include a (1) design for enculturation; (2) emergent-design; and (3) humanistic orientation. As a significant part of a recent Israeli Science Foundation Center of Excellence grant, we have been engaged in a large-scale project to design and construct a new facility to house our program, giving us the opportunity to scrutinize the relationship between LCs and FLSs. Below we describe three space innovations that correspond to our LC design.

To support *enculturation* of scientific practices, the space is designed to provide students opportunities to learn-to-be as well as to learn about content. Therefore, we coordinate between the processes and content of learning. For example, students study about LCs as they participate in one. We have accordingly designed part of the FLS to include research facilities, giving graduate students direct access to authentic practitioners to foster the enculturation of research practices (Hod & Sagy, 2015).

Flexibility is a key design aspect of the space based on the *emergent-design principle*. Our FLS will employ an innovative design called learning niches, which are noise-reducing partitions that fold in and out of the walls such that small groups of students can meet in private, with minimal interference from others but quickly be reconfigured to support interaction with the whole class. Other ways that we support flexibility are with easily moveable and combinable furniture, and an any-to-any communication system supported by embedded multi-touch screens, allowing for individuals or groups to collaborate with others via video, either inside or outside the FLS.

One unique aspect of our LC is its *humanistic orientation.* By this, we mean extended efforts to get to know one another, such that group dynamics (Hod & Ben-Zvi, 2015) and transformative changes in identities and long-held learning practices are challenged and negotiated (Gee, 2001; Hod & Ben-Zvi, 2014). To support the creation of a safe space so that students can engage in such intimate processes within a university setting, one of our main principles was to design the space with plants, rugs, a coffee bar, and warm colors to give it an inviting feeling. Likewise, we have repurposed several unused outdoor spaces with wooden decks and comfortable seating.

Facilitating bridges of practice among multiple learning communities
Michael M. Rook, Scott P. McDonald, Koun Choi, and Phil Tietjen

The Krause Innovation Studio on the campus of Penn State University is a technology-enabled and bring-your-own-device learning space designed to facilitate group collaboration and serendipitous learning interactions. The Studio also supports pedagogical innovation through staff consultations with faculty on learning theory, tools, and affordances of space. The Studio is arranged into learning pods and spaces; each pod/space is designed to facilitate sharing work via large screens. The Studio's design is grounded in communities of practice (Wenger, 1998), and it specifically considered how LCs form and are sustained (Rook, Choi, & McDonald, 2015). In the four years of the Studio's existence, the research team has collected iterative sets of data to investigate how LCs develop in the less goal-driven, open and collaborative spaces of the Studio. These data include: interviews with stakeholders

during the design and construction of the space; spatial use data (e.g., seating sweeps) collected over three years; and most recently phenomenological interviews focused on users' experiences of the space. The data collected thus far combine to provide an opportunity for our team to characterize the emergent and nascent aspects of an LC in an FLS designed to facilitate bridges of practice among multiple LCs.

The complexity of investigating informal, open and intentionally collaborative spaces has led the research team to explore multiple methods and a variety of theoretical frameworks to understand how several, overlapping LCs enact their practices. Initial research led to the characterization of design principles describing the learning theory-driven design decisions during the Studio's development: learning spaces should scaffold authentic practices; allow for multiple representations of learning; and be pedagogically responsive (Rook et al., 2015). These design principles are empirical and theoretically grounded in ideas about LCs.

The iterative studies also have provided us with two preliminary themes around how learners use the space. First, learners engage in a joint enterprise of knowledge construction (Wenger, 1998). However, unlike in traditional classrooms, joint enterprise in a FLS designed to support multiple learning communities does not necessarily map onto shared goals in the same way; instead, knowledge construction involves local goals, potentially as idiosyncratic as each LC in the space. Second, learners have a shared repertoire of practices including, but not limited to: tacit interactions, spontaneous meet-ups, and a shared sense of agency in how learners choose pods/spaces. We will present these themes with exemplars and inform the shared discussion by contributing an understanding of how multiple LCs interact within a shared, open, and goal-diverse learning space.

Endnotes

(1) Some examples can be found here: http://www.techinsider.io/the-13-most-innovative-schools-in-the-world-2015-9
(2) See lc.edtech.haifa.ac.il/injls for a list of articles within the *Journal of the Learning Sciences* that use LC frameworks.
(3) www.computerclubhouse.org

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Acknowledgements

Beyond Just Getting Our Word Out: Creating Pipelines From Learning Sciences Research to Educational Practices

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Abstract: This session convenes a symposium to discuss issues related to the gap between current learning sciences (LS) research and the majority of prevalent formal and informal educational practices internationally. Presenters will discuss their international experiences with building bridges between research and practice, such as such as commercialization, non-profits, and organizational and government supported programs. The session concludes with the presenters and the audience considering strategies and options for members of the LS communities to both "get the word out" as well as for future efforts to create pipelines for getting LS research into everyday educational practices.

Introduction

There is a serious gap between the important new insights into how students learn best and how best teachers can teach informed by research in learning sciences (LS) communities and the daily formal learning experiences for the vast majority of students at all levels and around the world. There have been important distillations of key research perspectives about how people learn that have been written for policy makers and educational professionals (e.g., Bransford, Brown, Cocking, & Donovan, 2000), and this research has contributed to national policy documents that reflect the latest research in the learning sciences, such as the NETP (e.g., U.S. Department of Education, 2010), learning and technology initiatives internationally, recommendations for STEM standards in the United States (National Research Council, 2012) and internationally, and so on. However, the reality "on the ground" in most K-12 schools and in universities is the majority of the commercially available educational products and services that are available do *not* align with research informed from the sciences of learning (e.g., see discussion in the final chapter of (Bransford et al., 2000)).

Compare the impact of research in other professional fields to the situation in education. In the medical and engineering fields, for example, important research based perspectives, products, approaches, and so on routinely move from the lab into the arsenal of products and resources that professionals in those areas are able to use. Put another way, there are *pipelines* for getting research from universities and labs to professional practitioners and thus to the general populations they serve.

A goal of this session is to convene a panel to discuss issues such as the nature of this gap between research and practice in education, and, more important, to consider approaches for members of the LS communities to both "get the word out" as well as perspectives for creating appropriate pipelines in our field. Examples of pipeline approaches that could be considered include "top down" ones such as large scale national initiatives that could fund centers bring CSCL LS researchers and industry partners together to create innovative educational products and services in different subject areas and grade levels. Other approaches include "bottom up" ones, such as formation of non-profit and for profit companies for bringing cutting edge research into formal and informal learning environments.

The session will start with opening comments for five minutes by the session Chair, Professor Peter Reimann. Each of the presenters will then speak for 10 minutes about their perspectives on the themes of this panel. We then take 15 minutes to have the audience members break into small groups to consider these perspectives as well as five minutes for each group to share with the entire group. We then have the presenters and the audience to discuss issues and perspectives and to spend the final 15 minutes to distill possible directions for future efforts to create pipelines for LS research to educational practices.

Starting a company in France: The personalization of multimedia content for different audiences

Kristine Lund

This presentation will first describe how the French government supports innovative technology projects that combine expertise from both the private and academic sectors. Second, I will present the company CogniK (cognik.net) that I co-founded in 2009, for which I am Chief Science Officer. Third, I will show how this pipeline, originally established for personalizing on-line educational games and videos for small children, permitted a number of different research topics in the learning sciences to emerge. Finally, I will present a set of tensions I have experienced while navigating between academia and the private sector. These tensions include reconciling research objectives with perceived market needs, aligning differently paced time-scales, and being encouraged to branch out from initial expertise, this latter leading to new research questions.

Beyond STEM and L2 in K-12: Opportunities and challenges for learning sciences research and practice at a business school
Ravi Vatrapu

This presentation will focus on an institutional initiative that involved translating and extending learning sciences research and practice from primarily STEM and L2 domains in primary and secondary school settings to business domains at the tertiary level at the Copenhagen Business School, Denmark. In particular, I outline and discuss some of the opportunities found, synergies created, and challenges faced between emergent research findings of EU integrating project of NEXT-TELL (www.next-tell.eu) and service initiatives at the institutional and national levels such as CBS Teach (http://teach.cbs.dk) and ICT in Higher Education. Finally, I include observations and reflections on the systemic differences in assessment regimes (Anglo-Saxon versus Danish/Nordic), the barriers to adoption and innovation due to the "not invented here" syndrome, and some possible solutions.

A professor meets the elevator pitch: Edtech startup lessons being learned in Australia
Michael J. Jacobson

Late 2013, the Research Office at the University of Sydney encouraged me to consider "spinning off" aspects of my research that had been funded by two grants from the Australian Research Council. Initially I was not inclined to do so as I lacked any business experience. However, I decided the research-based and theoretically-informed approaches for learning STEM subjects—such as the intelligent virtual worlds and computer modeling and visualization technologies my team developed—would likely never be used in regular classrooms in Australia or internationally unless affordable and supported products and services were commercialized by a company with a mission to enable transformative education. My company, *Pallas Advanced Learning Systems* (http://www.pallasals.com), joined the largest incubator in Australia in 2014 and is now getting traction with schools in the Sydney area and internationally. In my presentation, I discuss my lessons learned and being learned going from university research to founding an "edtech" startup company with the "lean startup methodology" being employed by many in the startup community in the US and internationally.

Research practice partnerships: R&D in and with informal learning organizations
Chris Hoadley

This presentation looks at the general scheme of design-based implementation research, and contrasts it with a different form of research-practice partnership as exemplified by two projects: the Hive Research Lab, a project commissioned by HiveNYC, a network of after school and out-of-school education providers, and the Mountain Project, a partnership between NGOs in Nepal and India and US-based researchers. In both cases, I describe how emergent capacities for thinking about reflection, inquiry, and research both support and sometimes conflict with traditional research stances, and discuss some of the ways in which research can be informed by the attempt to produce "usable knowledge" from the beginning. In both cases, research questions were partially driven by practitioner agendas, but were neither as practitioner-driven as participatory action research or classroom-based teacher research undertaken for data-driven decision making. I also consider the role of relationships as both a medium for and a limiting factor of scale, and highlight some of the advantages of partnerships that combine design and research.

Challenges bringing research-based products to market

Janet L. Kolodner

In 2009, the three-year comprehensive middle-school curriculum called Project-Based Inquiry Science (PBIS) was brought to market. Creation of the curriculum was the joint effort of many academics (Joe Krajcik, Brian Reiser, Danny Edelson, Mary Starr, and myself), our graduate students, post-docs, and research scientists, teachers we worked with, and a publisher known for publishing the best in "reform curricula" — It's About Time, Inc. The intellectual work of creating the curriculum was funded for a decade by the US National Science Foundation, and the research-based pedagogical approach focused on keeping learners excitedly engaged in sustained inquiry and reflection activities to foster learning from the project activities. Also, the curriculum aligned with the Next Generation Science Standards (NGSS). The curriculum has been adopted by many schools and school districts around the US, but not by enough to raise sufficient funds to keep it up to date with new technologies and new content standards. My lessons learned? I have identified a variety of challenges we faced in bringing research-based products to market in the US (and probably in other countries as well). The list is long: the need to market to each of thousands of school systems separately, shifting standards that make school systems fearful of new adoptions, and the lack of allocated funding for science education, especially in elementary and middle school. There is also a reticence towards adopting a curriculum that requires extensive professional development and learning of new teacher practices, and an enormous lack of understanding of what it takes to put together a coherent curriculum that really fosters understanding, knowledge integration, and cognitive flexibility, and inflexibility with respect to testing. Perhaps even more important is a lack of imagination about what schooling and learning could be. As part of addressing the challenge of bringing research-based learning products to real schools and real students, I propose that our community make a concerted effort to help the public better understand what learning entails and what education really could be.

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Building on Cultural Capacity for Innovation Through International Collaboration: In Memory of Naomi Miyake

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Abstract: This symposium addresses issues of scaling up research-based educational reforms, with focus on the Japanese Knowledge Constructive Jigsaw initiative--a substantial achievement of Naomi Miyake and learning science colleagues in Japan. Scaling up procedures involve small networks of teachers, education leaders and researchers working together to design, practice, and improve lessons across subjects, schools and districts. The set of strategies developed provides a common Knowledge Constructive Jigsaw framework or set of *"constraints"* to guide the practices of participants for reflection on learning and to expand children's potential to learn, teachers' potential to support student learning, and policy makers' potential to support teacher learning. Building Cultural Capacity for Innovation represents a vision shared by teams in Japan and internationally to transform schools into knowledge creating organizations, to learn from one another, and to—in Naomi's words--support a science of practice deeply embedded in the learning sciences.

Keywords: scaling-up, knowledge constructive jigsaw, knowledge building, DBIR

Introduction

This symposium is dedicated to Naomi Miyake, the former president of ISLS, who passed away May 2015. Miyake asserted and demonstrated that every child has the potential to engage in constructive interaction in order to learn deeply and find newer questions to explore (Miyake, 2013a). The symposium focuses on the Knowledge Constructive Jigsaw project led by Naomi in Japan—an initiative that has made significant advances in scaling up educational reform by building on cultural capacity for innovation and international collaboration. Knowledge Building International (KBI) members and KBI President, Marlene Scardamalia, worked with Naomi to realize a shared vision, as Naomi's ideas have many commonalties with Knowledge Building and "Building Cultural Capacity for Innovation (BCCI)" (Scardamalia & Bereiter, 2014). Complementary initiatives include transforming learning from more traditional, teacher-centric, didactic practice into future-oriented, learner-centric, knowledge constructive/creative practice, using a more insightful understanding of how people learn. If we can transform the concept of learning, we can empower all learners including students, teachers, school leaders and educational policy makers to build cultural capacity for innovation through educational reform. The question is how to turn the concept of BCCI into a reality in everyday practice through a "science of practice" (Miyake, 2015) deeply embedded in the learning sciences. Developing Naomi's ideas, we assume that every human has potential capacity for innovation and every culture innovative capacity through collaboration among its participants. Therefore, we named this symposium, "Building 'on' Cultural Capacity for Innovation" which declares that we can build upon existing but unseen capacity for innovation. The next-level question is how to build upon, or *draw out*, such capacity, which is the overall focus of this symposium.

Theory of "how people learn" as the core of educational reforms

Learning sciences have not made much impact on educational practices in Japan, in spite of innovations in learning theories and technologies (Law *et al.*, 2013; Penuel & Spillane, 2014). There is an unfortunate divide between cutting-edge works by learning scientists and large-scale educational reforms by researchers of educational systems and management, the latter of which do not take full advantage of the innovations. There is another unfortunate divide between teachers who make local innovations of "know-how" and educational researchers who cannot create nor implement learner-centric lessons, yet espouse *unfounded* theories or "know-why." Such researchers often give lectures to the teachers, direct them, and end up being distrusted. In order to change these situations, we need to restore the theory of "how people learn" as the core of educational reforms at every level from the classroom level to the policymaking level, and "craft coherence" of learner-centered, collaborative

knowledge construction among all members including students, teachers, school leaders, researchers, policy makers and stakeholders from the business sector. At this symposium, we will focus on the Japanese project to reform public education led by Miyake, which is rapidly being scaled up and has gained steady success. We will scrutinize both the key factors that promote project sustainability and scalability and those that hinder them, with the help of international collaboration.

<u>Integrative points illustrated through collective works</u>

In 2009, the University of Tokyo launched an initiative, the Consortium for Renovating Education of the Future (henceforth CoREF; http://coref.u-tokyo.ac.jp/), strongly grounded in the learning sciences in order to contribute to renovating Japanese education with two important strategic orientations. One is to bring university research closer to the policy makers at the ministry of education (MEXT) and the boards of education throughout Japan, so that university-level scientific knowledge has a better chance to become integrated in their curricula and to encourage scientifically-minded young learners. The other is to base such renovation on talks between the universities and the business sector, so that educational reform can be supported by society as a whole.

This project is one of the rare cases where the learning sciences have been adopted in earnest to guide renovation in classroom practices, using a concrete framework, "Knowledge Constructive Jigsaw" method (hereafter KCJ), with the joint efforts of the regional boards of education. This initiative is also unique in spanning all subject areas taught at all school levels, including elementary (1st to 6th grades), junior high (7th to 9th), and high schools (10th to 12th) across Japan, because the framework is not bound to the specific contents or practices of any subject. As a result, the participating teachers as well as the administrative leaders at the school and board of education levels are learning the sciences of how people learn, not in abstract forms but through implementing them in the actual classroom. In the following, Saito & Shirouzu (Paper 1) will illustrate the underlying theory, practice and assessment of KCJ with its preliminary outcomes. As a participating teacher, Ogawa (Paper 2) will report on her own version of "how students learn" through eight-year experience of KCJ in high school ESL classrooms. In order to help these teachers, Iikubo & Hori (Paper 3) will explain various implementation strategies that CoREF has been employing, especially forming networks of small networks (hereafter, NNs) of education leaders, experienced as well as novice teachers, to work together to design, practice and reflect lessons for the transformative evaluation, across subjects, schools and districts.

<u>The significance of the contributions</u>

This symposium will contribute to clarifying how to go beyond the hidden, negative factors of scaling-up. The biggest challenge for the CoREF project has been a fixed and uniformity-oriented mindset that has been absorbed by many students, teachers, school leaders and policy makers. One achievement in the reform history of Japanese education is the setting of clear standards for every school to make sure that the school can provide high quality education for every child. While this has been successful, we now also realize that this approach does not allow for sustainability and creativity, features which are crucial for the young today to make better worlds. Education needs to be changed from one that guides the students to achieve a set goal through a uniform process into one that helps every student go beyond such goals through her or his own process.

The first strategy that CoREF has adopted is the development of a new, concrete method of practice, KCJ, which has improved the individual progress of students who were not regarded to be "good" students but who were able to strive and perform at higher levels through constructive interactions. CoREF's assessment tools assess each individual's process of learning at short intervals and a lot more often, not through one-off answers to a set of test questions and/or interviews. This would make "formative evaluation" truly "formative" and "diversity" of learning outcomes clear. Coupled with the second strategy of forming NNs to appreciate and discuss such diversity, or *individuality*, the goal of the CoREF project is to foster the learning of individual learners, practitioners, researchers as well as society, together as a community of independent "learners." KCJ aims to draw out not only the children's potential to learn but also the teacher's potential to re/design lessons and understand children, as well as the educational policy maker's potential to re/design the support system for teachers. KCJ could be considered as "constraints" (Norman, 2013), by which we mean common elements that guide the practices of participants at every level for collaborative reflection on learning.

Key issues and contrasting scaling-up approaches

At a glance, the CoREF approach emphasizes the concrete images and know-how of collaborative learning. On the other hand, the Knowledge Building project emphasizes a principles-based rather than procedure-based approach for scaling up (Scardamalia & Bereiter, 2006), leaving "know-how" as a design challenge. These two projects therefore provide a fascinating contrast in approaches for scaling up, with different systems of *constraints.* Differences as well as shared visions have led over the years to intense conversations between KCJ and

Knowledge Building colleagues, as well as visits to each other's sites of innovation. The CoREF members now see constraints as lenses of the cognitive and learning sciences that effectively collect the high-quality, constrained data of learning processes, and provide an arena for collaborative reflection on learning. The constraints also can make the diversity of participants' mindsets of learning more explicit because participants base their discussions on a common foundation.

Building Cultural Capacity for Innovation
Marlene Scardamalia

"Building Cultural Capacity for Innovation" (shortened to "BCCI") is an international design, research, and development initiative to build cultural capacity for innovation in developing and developed nations, at all educational and socioeconomic levels. International partners are united by the idea that large increases in a society's innovativeness require building capacity for it, starting in early childhood, aimed at democratizing knowledge creation, and continuing through progressive development toward adult life and work in knowledge-based societies. BCCI is a research-intensive enterprise dedicated to the 21st-century principles of a place for everyone and knowledge for public good. BCCI research not only tests but creates innovations. Within the Knowledge Building context, the goal has been to create internationally distributed teams of innovators to support the spread of research-based innovations through global collaborative innovation networks. As suggested above, Knowledge Building represents a different scaling-up model with a different system of constraints from that used by KCJ. Naomi and Marlene spent many hours discussing different approaches as well as shared visions. Marlene will convey how they got from their different paths to a shared commitment to Building Cultural Capacity for Innovation.

Theory, practice and assessment of Knowledge Constructive Jigsaw
Moegi Saito and Hajime Shirouzu

CoREF has been working with the prefectural and city/town boards of education to develop learner-centric teaching curricula using KCJ. In Year 2015 (April 1, 2015 to March 31, 2016), this project is working with 184 core schools, 1136 core teachers and education leaders from 21 boards of education. Table 1 shows the scale of the project up until Year 2014. Teachers from elementary, junior-high and senior-high (officially from 2012) schools participated in the on-the-job training (OJT) workshops run by CoREF. All participants attempted some collaborative class teaching according to our guidelines and framework. The "core teachers" made select cases open online to be used for the purpose of lesson studies. Among such cases published online were 711 class practices complete with teaching plans, learning materials, students' performance records and a class video, which help provide next-generation participants with reference cases to kick-start their own trials.

Table 1: Number of participating parties and class practices by year

	2010	2011	2012	2013	2014
Parties *(Ed. board members)*	10 (15)	20 (27)	17 (92)	18 (73)	19 (122)
Core Schools *(teachers)*	23 (39)	70 (122)	125 (477)	152 (608)	189 (712)
Class practices on the CoREF site	35	102	121	179	274
Created in the OJT training	0	0	563	706	688

Three-level model of conceptual change and theory of constructive interaction
Cognitive studies on conceptual change have contributed to refine distinctions between naïve, everyday construction of knowledge and the construction of more scientific concepts. Miyake (2013b) proposed a three-level model of what kind of concept is acquired and how. The learning of concepts at Level 1 utilizes personal experiences. When a child "forms" a concept by experiencing one instance of some phenomenon, learning on Level 1 is said to have started. If the same child integrates his or her experiences of repeated encounters with similar incidents, he or she will be able to integrate them into a rule of thumb of Level 1. When the same individual is introduced to the concepts of others and/or more "scientific" concepts through media or at school, Level 2 and Level 3 learning starts. At Level 3, learners are required to learn scientific, state-of-the-art concepts in adaptive ways. There is usually a wide gap between the understandings of Levels 1 and 3, which often causes difficulty in school learning. The model provides as an intermediate level of Level 2, where the learner is expected to engage in repeated, rich collaborative learning experiences to modify the Level 1 understanding in various forms, so that

the learner is able to integrate them for the purpose of abstraction, to reach the Level 3 understanding. This is the reason why collaborative learning including KCJ is needed in school learning.

The question is raised as to why collaboration is thought to contribute to such abstraction. Miyake proposed the theory of "constructive interaction" which states that two persons, when engaged in solving a shared problem, exchange the roles of a task-doer who proposes possible solutions and a monitor who reflects upon such proposals. Such role exchange potentially promotes each participating individual's understanding of the problem, and eventually leads her/him to arrive at their own solution (Miyake, 2013b).

Framework of the Knowledge Constructive Jigsaw and its outcomes

The KCJ consists of five learning activities: (1) writing an answer to the day's given problem based on his or her rule of thumb, (2) an expert-group activity which allows each individual student to accumulate some pieces of knowledge relevant in solving the problem, (3) a jigsaw-type activity where students from different expert groups get together to exchange and integrate the accumulated pieces of relevant knowledge and form an answer, (4) a cross talk activity to exchange their ideas for solutions, involving the entire class, and (5) writing down his or her own answer again to the same problem and newer questions. This is a strongly scripted yet dynamically modifiable collaborative learning framework, developed from the Jigsaw method (Aronson, 1978) emphasizing the role of the shared "problem" for knowledge construction. The design naturally requires each student to become a task-doer in the jigsaw group, and provides each student with the chance to become a monitor who infers what the other students say and why they say that, in order to integrate the ideas of others with their own.

Concerning content achievements of KCJ, a comparison of the two answers given at the beginning and at the end of the class constantly shows the progress and depth of learning. Also, the content achievement levels of the KCJ classes measured with traditional tests tend to be high: for example, 60% out of more than 900 initial high school teachers who participated our OJT reported that they were higher than those of the regular classes.

In addition to the content achievement, we have assessed a new set of goals to be (1) portability, (2) dependability and (3) sustainability. The outcomes of learning have to be "portable" in the sense of being taken out by the owner in new situations; "dependable" in the sense of being usable in adaptive ways by the owner to identify and solve new problems; and "sustainable" in the sense of letting the owner ask new questions, become motivated to learn further and integrate them with new pieces of information for the creation of innovative ideas.

The portability of KCJ learning outcomes has been reported as high, even after six months to one year later (see Paper 2). For example, a science teacher at grade 4 posed the question of why a heated can collapses when cooled suddenly, to which 90% of the 30 pupils did not only answer correctly at the end of the class by integrating information they had gained through three experiments (cooling of a bag full of vapor; heating and cooling of a bottle of milk with a balloon on its top; cooling of a heated conical flask with a boiled egg on its top), but were also able to recreate their explanation one and a half months later. More than half of the pupils forgot to which experiment they had been assigned, indicating that the information was integrated as a "whole."

The dependability of KCJ learning outcomes is indicated by high performance on transfer problems and students' spontaneous mentioning of the outcomes on different units and subjects. When the science teacher mentioned above broke the boiled egg in pieces to take it out from the flask after the lesson, several students got together to ask, "Why can't we take it out without breaking it?" and proposed several ideas. A high-school history teacher reported that after teaching several units of European history by KCJ, his students developed the willingness to look into the complex, intricate dynamics behind the newly introduced "historical event," such as "Okay, so who was involved in what kind of roles? This thing cannot be explained by one cause, of course."

As the sustainability of KCJ outcomes, teachers appreciate students' desire to learn and ask questions. Students tend to increase the amount of "spontaneous homework," which is not assigned by the teacher, but they wish to extend his or her studies. Also when the scheduled class period ends before the intended activities are completed, the students kept working on the task during their lunch period or after school, often coming back to the next class with new, developed answers. Students also generate their own "next challenges," or advanced questions. After learning that a leaf of a tree looks green because it does not use the green spectrum of light for photonic synthesis, high school students asked, "Do the leaves of seaweed look brown because they need all the spectra of light?" or "Do the colored leaves stop photonic synthesis?" As another example, after learning how clouds in the sky are made, a junior high school student asked why water changes its state from liquid to gas at 100 degrees Celsius, and how common such a change of state is with materials on the earth.

Assessment tools for future

All the outcomes above came from the teachers' continuous improvement of their lessons, which is rare in an intensity of this scale in Japan. Next, why had the CoREF project been able to make differences to teacher learning? The first reason is the adaptability of the KCJ framework in the sense that the "problem (jigsaw task)"

and "learning materials (for the expert activity)" are decided by each teacher. The second reason is that the essential flow of activity allows constructive interaction to take place naturally and repeatedly. The last reason is that the assessment tools utilizing such observation chances can "visualize" the students' learning processes.

The first tool is "comparison of pre and post class comprehension," which simply asks the same question twice. Thanks to this, children can compare their own answers, and confirm whether they have seen progress, or *idea improvement*. Teachers can also compare the answers with their expectations, and ascertain to what extent children have deepened their understanding and how diverse their progressions and expressions are. The second tool is "multilateral dialogue analysis," which aims to auto-transcribe the students' conversations in all of the groups during the class and provide transcripts electronically searchable by keywords. The analyses showed students' trajectories to range from exploratory talk to elaboration of justification of their own judgment, as expected from the three-level model of conceptual change. Also, in the preliminary trials using the system for teachers, they said "We want to assess these conversations!" and "We can tell what kinds of interactions were taking place by looking for transitional expressions such as 'Why?' 'Huh' and 'I see'." In this way, by making formative assessments a matter of everyday practice, we aim to help teachers trace children's change in a very concrete knowledge space and raise the quality of education through continuous improvement of their lessons. This improvement makes us believe that every child has the potential to learn, and even when they fail, not children but designs of learning environments matter, which we can improve endlessly as a whole society.

Knowledge Constructive Jigsaw in order to acquire a communicative knowledge base in high school ESL classrooms

Sonoko Ogawa

Student learning in KCJ classes

Japanese ESL has a reputation of not being all that successful in promoting communicative skills in everyday life. The Knowledge Constructive Jigsaw can enhance the students' spontaneous use of English for practical purposes, including learning new pieces of information from various reading materials, and evaluating and integrating them to form an answer to the given problem of the class. Here I will give a report on student and teacher learning gained through experiences of introduction of KCJ to high school ESL classrooms.

We have implemented KCJ classes using such questions as "Why is there a 'standard' in the world?" or "How should you reply when you are asked by a friend to lend him/her your car key when he or she does not possess a driver's license?" We have analyzed the data of the students' notes, memos and conversations recorded during the class, decoded and analyzed after classes in cooperation of CoREF. The results revealed that the students gradually increased the expressive richness of their English writings and utterances, particularly when they were encouraged to compare and structure the piece-meal materials contributed by themselves as well as by other members of the class. To illustrate these findings, let me report on a reading lesson taught by the author for 11th graders, the day's theme of which was "why we need a standard".

The group of students studied are at the age of 16 to 17 at a highly academic all boy's school. The students were asked to write their initial answers to the question: "Why do we need a calendar?" In spite of their generally high performance in the national standardized testing and at least four years of experience of ESL learning, only 7 out of the 32 students could write anything at all at the beginning of the class. In addition, even among the students who could write grammatically correct answers, the answers were often very simple and superficial as shown in Table 2. What they wrote was basically defined by "what they had experienced in English writing lessons." On the contrary, when they answered the same question at the end of the KCJ class, all of them were able to write something as their "answers." They showed progress both in content and grammar.

In the expert-group activity, students read one short excerpt on the main idea – what a "standard is," or how it works – written in English. Then, students engaged in the jigsaw activity, talking about their ideas both in English and Japanese and gradually forming their own ideas about "standards," and were encouraged to express the idea in English at the end of the class. We can see how exactly they developed their ideas and refined their English from the recordings as shown in the excerpt below. Through this set of collaborative activities to construct an integrated answer to one target problem, students changed their concepts relating to the problem into more sophisticated ones, each in their own way. They also became accustomed to some useful English expressions to deliver their newly constructed ideas through these activities. It was a new experience for them to be able to express what they have just thought for themselves in a foreign language. This type of conceptual work, we hypothesized, should stay in longer-memory than a usual routine vocabulary learning.

In order to check this, the teacher conducted a spontaneous survey of 11 students from the class after a year, trying to test the knowledge's portability and sustainability. As a result, 10 out of 11 students mentioned the important ideas of the lesson in such as "standard," "common" and "share" (Table 2). These answers are advanced

in terms of English complexity and conceptual abstractness, and the reason seems to be that the core knowledge acquired a year ago was kept and expressed clearly, using vocabulary and syntax learnt later.

> Std B: How about "It tells us *seikakuna* (precise) date"?
>
> Std C: Let's see the handouts.
>
> Std A: Well, can we use the word… "exist"? No, "exact"?
>
> Std B: "Exactly" may be better (referring to a dictionary).
>
> Std A: You don't have to do that. "Exact" is also okay.
>
> Std A: "… Next, the calendar can offer a common time *kankaku* (sense)," I think.
>
> How do you say "*kankaku*" in English? "Time feeling"?
>
> Std B: The word "exact" is correct (still referring to the dictionary).
>
> Std A: How about "time feeling"? (Std C: tilting his head)
>
> Std B: "Time feeling" may be related to the clock. The calendar tells us the date.
>
> Std A: Well…, so how about "daily feeling"?

Table 2: Students' answers to the question of why we need a calendar, before, after and a year after the lesson

Std	Before the lesson	After the lesson	One year later
K	(NI)	I think we live everyday, consuming time like oxygen, food, and so on. We had better know how much time we had consumed and how much time is left for us.	I think a calendar enables us to keep connection with others in our daily lives. If it were not for a calendar, we would live independently.
T	A calendar have a function that let my life is going smoothly.	A calendar creates our standard of living. Without being the standard, we can't keep regular hours and feel relieved.	It keeps our standard living.
I	It teach me when the holiday	Calendars are used all over the world. But clocks are not. So, calendars give us the same informations.	(not surveyed)

Teacher learning from designing KCJ classes

Right now, I am in my eighth year of working with the CoREF research unit, and am still engaged in monthly teachers' workshops, material exchange sessions and on-line materials development. As the participants of this research group all have basic knowledge of KCJ, the teachers are equally respected when contributing to materials development. For example, when I reported online that "making worksheets very plain and structured, using a matrix box for example, has been found to be very effective in prompting the students' discussions at the jigsaw stage," other teachers soon afterwards started to use this criterion to review their lesson plans, giving suggestions and making changes. All of this actually happened somewhat at a distance from me, but I know and others kindly acknowledge that my suggestions started to spread. At the same time, I learnt or borrowed from other teachers' practices, adopted them in my own planning, and reported back on whether they worked in my classroom or not. Experienced teachers have a tendency not to acknowledge their *weaknesses,* but in this field of the CoREF teacher network, it is best to try and make errors and to give feedback to each other.

KCJ first challenges teachers and asks why we are here. In order to answer this question, we need to think really hard about why we are here and what exactly we want the students to learn and keep in their mind over the years. The answer seems to lie somewhere near the shore facing the sea of knowledge. Recognizing that we cannot teach unless the students learn is the first step. Then, the students will gradually take a ready step towards the unknown, questioning and finding answers together with their peers.

To me, KCJ is the way to unlock the reservoir of knowledge shared and constructed in class. A few years ago, I answered in an interview that "I do the jigsaw class when I want to learn with students on the same horizon. In that case, I try not only to be the facilitator and 'smoother,' but also to be a trick-maker or a confusion-maker, in order to let them think deeper." However, after attending more workshops and learning together with other teachers, I now think, if the teacher can help, he/she should help in such a way that learning in the classroom becomes more fun and meaningful. The KCJ framework made me think, alter my way of teaching and go beyond the psychological barrier novice or experienced teachers face: "I cannot do this and my students cannot do this."

In the development of learning science, a classroom teacher at elementary and secondary level has three roles. A specimen for a researcher, an on-going researcher, and a monitor to the relation of research and actual teaching experience. This third criteria of monitoring one's own teaching practice and recognizing the value of it in the light of learning science is a gift that this frame work of KCJ classes give.

Networking of networks of the Knowledge Constructive Jigsaw project

Shinya Iikubo and Naoto Hori

This paper reports DBIR strategies that CoREF has taken, especially its networking of small networks of participants. The strategies have mainly two purposes: first, establishing teacher communities of sustained lesson improvement with a focus on design and reflection of lessons within the shared framework of KCJ, and second, supporting the communities by administrative systems which develop in various, sustained forms.

For the first purpose, we have organized CoREF as tiered networks. CoREF leads the pedagogy, and provides frameworks for class practices, assessments, and schemes for running workshops, some as parts of a project activity and some as on-the-job training. The associated boards of education take the lead in concretizing the pedagogy into practice. The organization of CoREF is a hierarchically networked community, within which there are small, overlapping networks of many different types of combinations of teachers, schools, policymakers and researchers. The same teacher can belong to various communities simultaneously according to his or her needs. In other words, we do not recommend a rigid approach such as letting all teachers in one school participate in the project and start all at once, but a more flexible and dynamic approach.

The strategy for implementation is to spread the core pedagogy on how people learn in social contexts and on the learning science basis of collaborative learning practices. All the workshops and joint work between CoREF and its associate members are designed with this strategy, so that the participants can explain the core pedagogy. For example, the first workshop always has teachers directly experience KCJ lessons. These newcomers do not only experience the lesson as students but also reflect upon the improvement of their own answers from pre to post-class, which makes the impossible possible to realize that, even when students are diverse, they surely improve their own understanding. In some workshops, the newcomers exchange experiences of two different types of KCJ lessons to extract "what the KCJ is." The strategy thereafter can be done in diverse ways, such as creation and sharing of practice plans and materials, co-constructions of new lessons, opening their classes to be observed and discussed by newcomers, and developing new assessment methods to better communicate the foundations and outcomes. In expanding these networks, we have come to realize that the needed conceptual change is promoted by providing the newcomers with already established teaching plans, with matching learning materials, so that they can "experience" the differences. To do this, we need lots of good plans, already tested-out in classes, with "practical principled knowledge" conveyed through vivid stories by experienced teachers, which we publish on our website and as a handbook.

For the second purpose, the project has impacted organizations especially through connecting originally divided networks and overlapping networks of differed layers. Our movement had the education boards restructure its teacher support sections as well as the OJT sections, so that those two sections, which have been working independently, work together for better results. In addition, CoREF and an education board of Saitama prefecture conducted personnel exchange which was the first case in Japan: the two persons concerned in Year 2015 are the authors of this paper. After this exchange, the Saitama prefecture and CoREF accelerated overlapping of networks. Figure 1 represents the relations among projects and OJTs. When we started official OJT for initial teachers in Year 2012, we heard that the teachers felt alone inside and outside their schools when implementing KCJ lessons. Thus, we conducted training for supervisors and school leaders so that KCJ could be shared as a common framework to demonstrate and discuss how students learn, regardless of whether they agreed with the framework or not. Accumulation of these projects and OJT during the five years also yielded many experienced teachers who need places and partners to discuss their versions of how people learn. We started the project for nurturing "KCJ and lesson study masters" by collecting applicant teachers from all around Japan up to forty, providing them with more advanced contents of the learning sciences and letting the teachers connect them with KCJ experiences as well as discuss their learning sciences. These teachers are now not only guiding newcomers but also travel all over Japan to conduct KCJ lessons for students in many districts.

Transforming learning at the DBIR level does not mean that a researcher or government committee has the one and only answer to hand down to teachers, but that everyone brings her or his own answer and interacts with one another to construct better solutions, the principle of which should be exactly the same with classroom learning. This is what Miyake wished to realize through her theory of constructive interaction, through the framework of KCJ and many implementation ideas. For teaching learning sciences as learning sciences teach us, we need a concrete form of KCJ. By implementing our initiative around that framework as a shared constraint (this is why we use this word instead of "script"), we find that we can turn the learning sciences into a more real science of practice. That science draws out the children's capacity for yielding new questions, the teachers' capacity for designing new lessons (and even revising the framework and creating their own ones), the administrators' capacity for new systems, and the researchers' capacity for finding new challenges, all of which contribute to building a cultural capacity for innovation based on our potential.
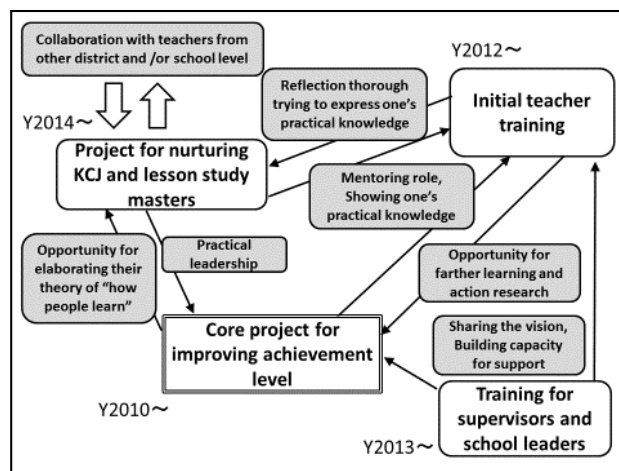
Figure1. Network of projects and OJTs conducted by the education board of Saitama prefecture.

International panel: Partners in Building Cultural Capacity for Innovation

Naomi knew her vision required teams of scholars, practitioners, and policy makers; in that spirit we assemble an international panel of colleagues, some she never met but would be proud to know, who can advance the Building Cultural Capacity for Innovation initiative. Panelists will be representatives from the Americas, Europe, and Asia-Pacific Region. They include directors, deans, and representatives of creative and large scale initiatives to advance education.

In order to lead the discussion, Scardamalia will describe "an international design lab to foster education for innovation." Plans include Knowledge Building innovation networks to connect students, teachers, and administrators; creation of national, linked, hubs of innovation; professional development to reach large numbers of teachers; new technologies and tools to empower teachers and students; data sharing to enable feedback to support ever more advanced accomplishments; resources configured in creative commons with clear research bases; and infrastructure for an initiative international in scope. Overall, the initiative will feature school-university-government partnerships, be research intensive, and span all subject areas taught at all school levels. Partners to the Building Cultural Capacity for Innovation initiative are committed to advancing education in their home nations and through international collaborative arrangements. The final part of the symposium will be devoted to an open discussion between symposium presenters and audience to discuss formal international partnerships needed to share data and to work together.

Naomi's vision for a research based science of practice included designs to share big data not only of achievements but also of learning processes, and to support reflection and action research. Carolyn Rose is the Principle Investigator of a new National Science Foundation award: Big Data Collaborative: From Mining Massive Data Sets to Designing Support for Explanatory Coherence, Consensus, and Action. Carolyn will provide a brief overview of the significant new opportunities for international partners to engage in this research.

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Exploring the Value of Drawing in Learning and Assessment

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Abstract: Drawing is increasingly recognized as a literacy of science. It is claimed that when learners draw they engage in ways that help them evaluate and transform their understanding, practice fundamental disciplinary practices and provides the basis for formative or summative assessment. This symposium draws together research on student drawing across different disciplines (e.g. Chemistry, Biology, and Anatomy) to explore the value that drawing can have in learning science and medicine. Importantly, the papers take a nuanced view of the value of drawing; attempting to avoid the sometimes overblown claims that accompany calls for particular approaches to education by addressing situations when drawing has been found to be ineffective as well as helpful. They will also focus on analysis of process data (e.g. drawings) to provide insight into when particular representational practices are helpful and how they must be executed and supported to gain these benefits.

Introduction

It is well accepted that a range of disciplinary practices underpins a working understanding of scientific knowledge. We argue with others (e.g. Ainsworth, Prain & Tytler, 2011; Lemke, 2004) that drawing is an important disciplinary practice in science and medicine. Drawing plays a number of important roles as scientists work and as students learn. For example, analyses of the processes involved in science discovery has shown that scientists draw to transform their understanding (Gooding, 2004). Epistemic practices in the sciences entail reasoning about relationships between multiple, multi-modal representations including drawings, material instruments and phenomena (Nersessian, 2008). Students need to learn how to reason through visual, linguistic and mathematical modes to generate, coordinate and critique evidence and this often involves models and model-based justification (Lehrer & Schauble, 2006). Drawing can support communication between colleagues as they participate in the day-to-day activities of science (Kozma, Chin, Russell, & Marx, 2000) or in a range of formal or informal assessments (Cooper, Williams, & Underwood, 2015). However, the rationale for including drawing differs across disciplines as does the way that drawing activities unfold. Consequently, this symposium explores how students in science and medicine use drawing in similar and unique ways.

Stieff and DeSutter explore the value of adding drawing activities for promoting learning when students engage with dynamic visualizations in chemistry. Students drew up to six times – each time creating an observation sketch of the simulation and reflective sketch of their new understanding. These students were compared to students who followed the same curriculum but did not draw. They found a small but significant effect of drawing and that students who drew more frequently learnt more. Panagiotopoulos and colleagues explore medical students drawing when they learn anatomy in pre-clinical dissection classes. They asked beginning students to draw pre and post dissection and compared these drawings to third years on clinical placement. Their research suggests that students come with expectations strongly formed by textbooks and popular culture, especially for familiar organs such as the heart. Dissection activities, if anything, seemed to destabilize their understanding without replacing it with anything more correct. However, by the third year their drawings showed an increased

understanding of the overall shape of the heart although this did come at the cost of specific knowledge of its features. Tytler and Prain present findings from their on-going exploration of the roles of representation construction, including drawing, across a range of school science topics. Their work describes how students use drawing in diverse ways to support their learning and reasoning. Moreover, by comparing the situations where drawing was found to be helpful to those where it was not, they provide guidance for how to use drawing in the classroom. Van Joolingen et al describe an innovative approach to modeling in science. Students created an executable model to express their understanding of scientific phenomenon. However, rather than using complex algebraic expression or artificial graphical formulisms they simply draw the model in a microworld, which the system interprets and animates according to the behaviour described in the model. This paper presents a study of secondary school students learning evolutionary biology through drawing based modelling and reveals how the design of tools, as well as the way students were prepared strongly influenced the effectiveness of this approach.

These papers share the view that drawing can be valuable but illustrate important differences. They combine experiments, ethnographic study and design-based research to understand drawing in learning. By presenting these papers together, we address a number of important points. The first concerns what these students were drawing: from anatomical structures through simulations, models, experiences and abstractions. Drawing was used in assessment, communication, in classroom and as homework. Together they illustrate the ways that drawing is used to support the learning of many different aspects of science and medicine and their assessment. This provides the opportunity to consider if there are distinct disciplinary differences in the ways that drawing should be considered. A second important issue raised is how drawings should be analyzed and what information we need beyond the drawing to analyze the approach. Stieff and DeSutter count the number of drawings and relate them to test scores whereas van Joolingen et al explore the talk around the drawings, Panagiotopoulos et al analyze 10 distinct aspects of each drawing and Tytler and Prain capture video data of the process of drawing to learn in classrooms. Understanding that drawing is an authentic practice in many domains has only recently been widely accepted in the learning sciences and as a result compared to such practices as argumentation and writing, we do not yet have much knowledge about how to study and code the process of drawing and the drawings that result. All participants will make their approach explicit so that with the help of the discussant and audience we can improve our knowledge. Another issue that all participants' address is to consider when drawing or approaches to drawing are **not** helpful. The path of over-excited claims about the benefits of an approach to learning followed by a retrenchment as the evidence does not support those claims is a familiar one. By focusing on the situations when drawing has not been shown to be effective we hope to avoid this path and make our approaches more nuanced from the beginning. Our discussant Puntambekar will contrast these four perspectives to help a s a c h i e v e a better position to appreciate the costs and benefits involved in using drawing in learning and assessment, as well the challenges for researchers to understand these activities and how best to enact them.

Drawing from dynamic visualizations
Mike Stieff and Dane DeSutter

Recent reviews regarding drawing to learn (Van Meter & Firetto, 2013; Waldrip & Prain, 2012) have reported few studies that investigate the efficacy of drawing activities in STEM classrooms, and the results of these studies have been varied. Such work suggests that drawing can be beneficial for science learning, but empirical studies demonstrating when drawing supports STEM learning and how to capitalize on the benefits of drawing remain outstanding. Notwithstanding the limited evidence, recent innovations for teaching science have begun to integrate drawing activities more centrally into curricula that include complex dynamic visualizations, such as animations and simulations. Dynamic visualizations direct learners' attention to information that is typically not present in texts or illustrations and the extent to which drawing activities support, replace, or enhance learning from visualizations is unknown. Moreover, there is some empirical evidence that drawing activities may not effectively support learning from dynamic visualizations any more than other instructional scaffolds. For example, studies regarding learning in high school chemistry classrooms (Stieff, 2011; Zhang & Linn, 2011) have reported marginal effects of coupling drawing with dynamic visualizations compared to activities that do not involve drawing. More recently, Zhang and Linn (2013) reported that drawing is no more effective than activities that involve

simply selecting information presented in a visualization. Here, we report on the results of a large-scale efficacy study that compared the impact of Connected Chemistry Curriculum (CCC) activities that couple dynamic visualizations with drawing activities to learning activities without visualizations or drawing. 92 students (drawing group) completed six one-hour CCC homework activities during their normal course of instruction in an undergraduate general chemistry course, and 413 students learned the same content without using the CCC activities (problem solving group). The CCC activities involved students engaging with a dynamic simulation of molecular behavior to investigate a core disciplinary concept. Students sketched at least twice while completing a guided inquiry investigation using a CCC simulation. Students completed an *observational sketch* that represented what they viewed in the simulation; Students then completed a *reflective sketch* that represented their mental model of a novel chemical system after completing the activity (Figure 1). Activities were administered approximately every three weeks over a four-month period and completed individually. Participants in the problem-solving group completed an algorithmic problem solving worksheet related to the six concepts targeted by the CCC activities.
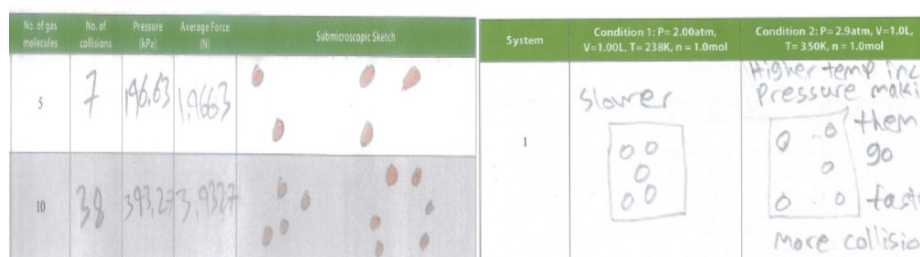

Figure 1. An observational (LHS) and reflective sketch (RHS). The activity moves from observational sketches of a closed gaseous system to reflective sketches of an unknown gas under two conditions.

Learning outcomes were assessed with a 22-item fixed-choice achievement assessment developed by the ACS (American Chemical Society, 2001) that students completed on the first and last day of instruction. Learning outcomes were analyzed using repeated-measures ANOVA with college GPA included as a covariate. The analysis revealed a significant difference between groups ($F(1, 500) = 4.89$, $p = .027$, $h_p^2 = .01$) with students in the drawing group ($M = 9.87$, $SD = 5.8$) slightly outperforming students in the problem solving group ($M = 9.24$, $SD = 2.7$). To isolate the contribution of sketching activities to learning in the drawing group, we performed a parametric linear regression in the Bayesian framework. We chose a non-informative prior distribution, given no prior knowledge of the true parameter values in the regression model. A Monte Carlo Markov Chain sampled from the posterior parameter densities over 20,000 iterations, pared down by preset burn in (2,000) and trim (5). Posterior density estimates of regression parameters at the 50% confidence interval indicate that participant pretest scores (β_zPreScore: [0.509, 0.618]), institutional grade point average (β_zGPA: [0.087, 0.205]), and the number of times they engaged in drawing activities (β_zDrawing_opps: [0.063, 0.178]) were all positively associated with posttest scores. Similar results were found on a subset of posttest conceptual items that explicitly invoked submicroscopic representations: posttest scores were positively associated with pretest score (β_zPreScore: [0.444, 0.561]), GPA (β_zGPA: [0.043, 0.172]), and the number of completed drawing opportunities (β_zDrawings: [0.013, 0.139]).

Consistent with early studies, this study shows that sketching may not yield a large, positive impact on learning in STEM disciplines, particularly when coupled with dynamic visualizations. While we did find that students who completed a general chemistry college course using CCC materials slightly outperformed students in the comparison group on a learning outcome measure, our analysis indicates that this difference was only weakly related to completing the sketching activities themselves. Although we did not find a large benefit of sketching for improving STEM learning in the present study, we believe additional studies of sketching as a learning scaffold are needed. The optimal design of a sketching activity remains poorly understood, but at the least our work has shown that simply producing sketches while viewing a dynamic visualization can marginally improve learning outcomes.

Drawing within experimental exploration as part of core epistemological and epistemic practices in science

Russell Tytler and Vaughan Prain

This presentation explores drawing in the context of a guided inquiry approach to teaching and learning science where students engage in guided representational challenges to explore the attributes of, and make claims about, phenomena. In this approach, constructing representations in general, including drawing in particular, operates in tandem with experimental processes to productively constrain reasoned exploration and explanations of material phenomena (Prain & Tytler, 2012). We argue that the epistemological processes central to this representation construction inquiry approach mirror epistemic practices in science. This approach encourages experimenting with and integrating visual as well as more traditional text-based literacies. Our perspective follows pragmatist accounts of the situated and contextual nature of problem-solving and knowledge generation and so we describe an empirical and systematic method of inquiry that involves a collective analysis of explanatory accounts of phenomena to establish reasoned knowledge, avoiding a priori judgments. Representations actively mediate and shape reasoning such that classroom activities focus on the representational resources used to instantiate scientific concepts and practices. In traditional accounts, representations are often cast as efficient and effective ways to introduce and illustrate abstracted concepts that are conceived of as distinguishable from the representations through which they are generated and communicated. From our perspective however, representations including drawing are the reasoning tools *through which* we imagine, visualise spatial relations and model astronomical phenomena. This view is also fundamentally Vygotskian, characterising representations as the disciplinary language tools that mediate thinking and knowing (Moje, 2007).

We will present ethnographic analyses of video sequences where groups of students respond to an open task by exploration, drawing, and talking to reason about phenomena. Our aim is to investigate a) the variety of ways that drawing operates to support reasoning and learning, b) the conditions when drawing is effective in promoting quality learning. As part of the analysis we investigate counter examples where drawing does **not** substantially contribute to the learning and the features of tasks including teacher framing and support that are important to ensure drawing contributes to learning in ways consistent with epistemological opportunities and practices in scientific drawing. We report on two types of study, each involving video capture of primary students' interaction with objects in groups, to draw and otherwise represent their reasoning to problem-solve and explain:

1. classroom situations where teachers are developing the representation construction approach and students are engaged in representational challenges as part of coherent sequences in topics of astronomy, invertebrate studies, and consumer science.

2. single lessons in a specially designed learning classroom with 10 wall and ceiling mounted video cameras with zoom and tilt capacity, and radio microphones on each desk, controlled from a room with visual access. Single lessons were conducted for the topics of levers, flower classification, toys, and astronomy.

Analysis was ethnographic with group investigation, drawing and discussion selected to represent a variety of ways in which student drawing supported, or was ineffective in supporting, student reasoning and learning. First, in relation to a) the ways in which drawing contributes to reasoning and learning. 1) representing through drawing was effective in framing/constraining student attention to relevant details of phenomena, in forcing a focus for instance on details of flower structure, or of toy mechanisms and their interrelations 2) drawing acted as a self-check on student perceptions in that errors in perspective or interpretation were exposed, enabling correction 3) drawing acted as a common ground through which groups of students reached agreement about the visuo-spatial aspects of the problem requiring explanation 4) drawing exposed visuo-spatial aspects of student conceptions that were accessible to teachers and provided an opportunity for negotiation of meaning 5) drawing was effective in framing student observational and conceptual attention. Second, in relation to b) the conditions under which drawing was or was not effective, a distinction could be made as to whether drawing was used as a generative part of the reasoning process, or as an 'after the event' communication device. In tasks where students had been introduced to appropriate representational resources, drawing could be generative and creative. Where the task was conceptually difficult, without appropriate support, students could revert to ineffective abstracted verbal explanations with drawings not adding to their understanding. In cases where students were not engaged with the representational task as personally relevant, drawings could be subservient to talk and gesture, and lack explanatory detail. In general, in such cases, explanations were superficial.

The study has demonstrated the important role that drawing can play in inquiry approaches to

conceptual learning in science. It revealed the ways in which students generate drawings that are more than copies of text or board productions to reason and learn. It also identified conditions needed for drawing to be effective, and the possibility of superficial and ineffective use of drawing if students are not engaged with the task and do not have appropriate representational resources and supports.

Drawing the body: Medical students understanding of internal organs

Dimitrios Panagiotopoulos, Shaaron Ainsworth, and Peter Wigmore

In the development of the medical practitioner, learning anatomy is considered critical. However, the value of dissection sessions is more contested with many UK medical schools removing them. Dissection classes often offer students their first hands on experience with internal structures of the human body and so those that argue for them suggest that they support students' understanding of the 3D organization of the human body (Older, 2004). Moreover, prior knowledge that students have for anatomy has been strongly influenced by the representations used in their prior education or found in popular culture. Unfortunately, in the case we will discuss, the human heart, this representation is at best partially complete and frequently profoundly incorrect. In this presentation, we focus on drawings use to assess students' understanding. The current approaches to assessment at Nottingham ask students to provide verbal descriptions after each dissection class and formal assessment is a written online multiple-choice test. This is unfortunate as students can produce or recognize appropriate verbal labels (e.g. hydrogen bonding) when their drawings revealed profound misunderstandings (e.g. Cooper et al, 2015).

At Nottingham the sequence of anatomy teaching activities repeats biweekly. Students learn about specific structures from a lecture before attending a dissection class, where following a briefing, they conduct a dissection (in small groups) lasting roughly 60 minutes. We asked 1st year medical students to draw the external features of the heart either before (N=44) or after its dissection (N=54). The heart is the second structure dissected. We also attended a clinical placement session and gave 3rd year medical students the same instructions (N=46). We developed an extensive coding rubric. To analyze specific features of the heart, the number of features were counted (total = 28) as well as whether they were correctly shaped, located and labeled. We also analyzed the shape of the heart. We coded the overall shape of the heart by diving width by height (a human heart in its natural state is about 20% wider than higher) as well as the point of maximum width (around 60% down in reality) and maximum height (around 40% to the right, so typically drawn 40% to the left in medical textbooks). Representational choices were analysed independent of content. 10% of these data were checked (all kappas above .7).

Table 1: Drawing analysis results by condition

	(1) Pre Dissection	(2) Post Dissection	(3) 3rd year	ANOVA (F,2,144)	Post hoc Comparisons
Features Present	52.6% (17.7)	45.4% (13.9)	37.8% (17.9)	9.11, p<.001, $p\eta^2$ =.114	1 v 2 = .096, 1 v 3 = .001, 2 v 3 = .070
Accurately located	39.3% (16.9)	34.5% (13.3)	27.5% (15.3)	6.99 , p<.001, $p\eta^2$ =.090	1 v 2=.352, 1 v 3=.001, 2 v 3=.068
Accurately shaped	37.7% (16.3)	32.3% (13.8)	25.8% (14.0)	7.42, p<.001, $p\eta^2$ =.095	1 v 2=.218, 1 v 3=.001, 2 v 3=.087
Accurately labeled	53.8% (30.3)	36.7% (31.4)	6.4% (19.4)	33.91, p<.001, $p\eta^2$ =.325)	1 v 2=.009, 1 v 3=.001, 2 v 3=.001
Overall Shape	101.7% (16.6)	101.1% (20.6)	107.9% (19.4)	1.83, p=.164, $p\eta^2$ =.025	1 v 2=1.00, 1 v 3=.386, 2 v 3=.234
Depth of Max Width	53.6% (13.5)	46.5% (17.0)	61.4% (18.5)	10.0, p<.001, $p\eta^2$ =.124	1 v 2=.113, 1 v 3=.082, 2 v 3=.001
Point of Max Height	56.1% (14.8)	57.2% (14.8)	46.8% (16.0)	6.65, p=.002, $p\eta^2$ =.086	1 v 2=1.00, 1 v 3=.013, 2 v 3=.003

Analysis of the features showed a multivariate effect of condition (F(8,278) = 8.24 p<.001, $p\eta^2$ =.192) with all four variables showing a main effect of condition. Tukey tests revealed the same pattern for

all variables: i.e., that before dissection 1st years draw hearts which were richer in accurately labeled shaped and located content compared to 3rd years with 1st year post dissection being somewhere in the middle. Analysis of the overall shape of the heart showed a multivariate effect of condition (F(6,280), = 3.86 p=.001, pη^2 =.076). Although there was not a significant improvement in students' drawings of the overall shape, the specifics of this shape did improve with students in third year showing shapes which placed the points of maximum width further down (which is more accurate) as well as the point of maximum height being further to the right, which also is more accurate (all Table 1). Finally, three chi squared analysis considered the representational choices of students. Here there was less of an effect as there was no difference in how they used color χ^2 (4, N = 144) = 1.69, p = ns) or drew in 3d (4(n = 144) = 1.74, p = ns), however third year drawings were on average more "sketch" like and were judged therefore as less clear χ^2 (4, N=144)=11.03, p=.026).

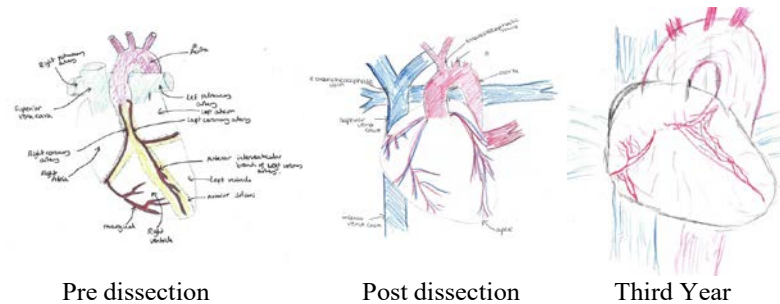Pre dissection   Post dissection   Third Year

Figure 2. Three typical hearts from the different conditions.

Our predictions were only somewhat supported. Third years did show greater understanding of the way the heart is shaped but at the expense of remembering specific features. Moreover, students were no more accurate in their drawings of heart after dissection and in fact they were typically slightly or significantly worse depending on the measure. We suggest that dissection for these students (an undeniably affectively demanding part of medical training, especially at the beginning) did destabilize students' reliance of the prior "textbook" knowledge of the heart but did not quickly replace it with something more accurate. This study therefore does not unambiguously reveal whether dissection is helpful or unhelpful; longitudinal studies would be needed. We suggest that this research shows that drawing as a mode of assessment in anatomy is of mixed value. It is very helpful for assessing students' understanding of the spatial aspects of internal anatomy, especially shape. However, assessing specific content is time consuming and we feel adds little beyond that which could be more swiftly assessed from written texts. Currently, we are conducting grounded interviews with anatomy lecturers where their evaluation of these drawings will be compared to our assessments.

Drawings to create models of evolutionary biology
Wouter van Joolingen, Dewi Heijnes and Frank Leenaars

In computer modeling, students create models of scientific phenomena. Many modeling systems require skills in either programming or equation writing (Louca & Zacharia, 2011) making modeling less accessible to younger students. We have tried to overcome this drawback by using drawings as a basis for the creation of computational models, and so enhancing \ scientific reasoning in young students. Using a drawing-based modeling tool, students created models of evolutionary biology. The modeling task is loosely based on natural selection of the snail species *Cepaea nemoralis*. These snails have a shell color that matches the background color of the area where they live, which is explained by them being hunted by birds: snails that are camouflaged are more likely to avoid predation and pass on their genes. Students involved in the current study used SimSketch (Bollen & van Joolingen, 2013) to create their model from a drawing. Elements in the drawing are assigned with user-defined *behaviors*, which are represented as "stickers". In this case, students draw snails, birds and areas where snails can live. Snails are assigned moving and reproductive behavior, with a probability of mutation of color on each reproduction. Birds receive a behavior to predate on the snails. The areas serve as background and the probability of being eaten depends on the color difference between snail and background.

Students from grade 7 and 9 worked on the assignment during one class period of fifty minutes. 15 minutes were spent on introducing the context and explaining the workings of SimSketch, 30 on modeling and 5 on discussing what students thought of the experience. Students' scientific reasoning was analyzed to determine what elements in the assignment and modeling tool have an influence on scientific reasoning. We used three iterations of data collection, each with a modified version of SimSketch, based on the results from the previous iteration. Their conversations were analyzed using part of the method for assessing reasoning complexity used by Hogan, Nastasi, and Pressley (1999). Reasoning complexity is used to gauge the quality of students' learning, which focuses on their ability to explain and elaborate on their understanding, rather than on comparing their knowledge to that of experts. For each iteration, the main results are described Table 2.

Table 2. Overview of the main results of the three iterations in the study.

No.	Students	SimSketch Features and assignments	Main findings	Reasoning
1	4, grade 7	Basic version, three areas for snails	Reasons outside the model are used	Generally low
2	6, grade 7	+ Hunting behavior modifiable by the learner.	More reasoning within the model, less outside causes.	More complex reasoning
3	2x6, grade 9	+ 2 instructions 1) focusing on research questions, 2) on the modeling tool itself Statistics tool added.	Students with instructions about the modeling tool act more playfully.	More complex reasoning when instructions focused on the modeling tool

A key finding from these iteration is that details in the design of the modeling tool can have substantial influence on the reasoning behavior of children. For instance, in the first run, children expressed reasoning that involved "magic" arguments from outside the model:

T: What is, you think, the influence of the colors of the areas on the snail shells- on the colors of the snails? S: They become… darker?

T: How so? S: Because the green color influences it or something, or it makes them have darker children.

T: Why would that make them have darker children? S: Because they take up a bit of the pigments or something?

T: From the leaves? S: Could be.

However, in the second study in which students now explicitly modified the hunting behavior of the birds typical reasoning:

T: How does it choose which snail it hunts? S: On the one that is closest- random.

T: Why at random? S: They can also go at the prettiest. But now- If they just pick the one that is closest. That is the most logical, really. That they hunt the one that, that they are like 'oh see there is the snail I'll take that one'. You know, they are not going to fly ten kilometers to get him if they have already seen fifty.

The third iteration of study contrasted two groups to explore how best to prepare students to model to learn. In the first group, emphasis was placed on the research question as students were asked early on what they thought was going to happen with the colors of the snails and the explaining the workings of SimSketch was put in second place, whereas, for the second group emphasis was placed on explaining SimSketch. Students in this second group spoke more about the modeling process in reasoning terms than the first group (a total of 87 utterances versus a total of 36). As expected, students who worked on the modeling task with SimSketch were generally able to create a model of evolutionary processes and reason about this model. This is a solid foundation to build from and to consider improvements to the tool design and the nature of instructions to enhance students' reasoning. We conclude that as students display more appropriate reasoning when they are able to modify the bird's behavior this indicates there is probably a minimum level of control needed in the modeling processes. By constructing the cause for the hunting behavior themselves, students were

encouraged to include that in their reasoning about evolution. The result of the third study indicates that keeping the modeling task open, by not focusing too much on the research question, actually engaged students in deeper and more complex reasoning about the domain. This seems in contrast with earlier studies in which the modeling tasks were heavily scaffolded (Mulder, Lazonder, & de Jong, 2014). Their models improved with more scaffolding. However, in that study students' reasoning processes were not studied. The current study is an indication that too much scaffolding and automation of modeling processes may get in the way of learning from the models and modeling processes. This informs the design of drawing-based modeling tools, lessons and further study.

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Designing Learning Contexts Using Student-Generated Ideas

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Abstract: This symposium proposes a genre of learning designs called Student-Generated Ideas (SGIs), based on designing learning contexts that promote students as critical producers, distributors, and consumers of knowledge. SGIs place students' ideas at the center of learning designs, considering the learning process as well as the learning goals/outcomes. By soliciting and foregrounding students' diversified ideas in the classroom and beyond, the learning environment communicates to students that their ideas matter to others and that they have a position of responsibility to their own and their peers' learning processes. The notion of SGIs is embodied in a repertoire of studies at the Learning Sciences Lab, National Institute of Education, Singapore, that offer varied yet overlapping interpretations of how student ideas can inform the design of learning contexts. In sharing the core design principles for SGIs approaches, this work contributes important components to the learning sciences discipline and changing educational practice.

Keywords: Student-Generated Ideas (SGIs), Productive Failure, preparation for collaboration, language demands of science, learning in makerspaces, game-based learning, seamless learning

Introduction

Student-Generated Ideas (SGIs) embody principles for the design of learning environments that promote students as critical producers, distributors, and consumers of knowledge. Rather than focus on mastery of expert knowledge, a major goal of 20th century education, SGIs leverage students' ideas as the basis for designing educational settings. Putting students' ideas at the center of the classroom communicates to students that their ideas matter to others and that they have a position of responsibility to contribute to knowledge advancement in the classroom community. Highlighting the inquiry process of the student intends to support students to take control of their learning processes. In this way, students not only learn the target subject(s), but also come to understand the means for working with and creating knowledge (e.g., finding problems, re-representing or re-modeling knowledge, locating resources, testing ideas through experimentation, developing skills in argumentation and the critique of various perspectives, etc.). The burden of SGIs research is to design a smart context rather than to assess a student as a "smart" or "not a smart" individual (Barab & Plucker, 2006). Through such designs, student "ability" becomes a function of context, expectations, and tasks. These designs promote engagement and are founded on learning potential, rather than formally measured achievement.

Our proposed symposium on the SGIs approach is built on a strong foundation of studies at the Learning Sciences Lab, National Institute of Education, Singapore, that create classroom innovations for 21st century learning. These studies have been carried out using a variety of contexts (formal and informal), domains (mathematics, science, language, etc.), tools (computer-mediated communication, mobile technology, game designs, etc.), and schools, and thus, present an opportunity for building invariant meta-design principles across the variant particulars of our projects. The design and enactment of SGIs research necessitates intensive collaboration with classroom teachers, not always but typically, through design-based research or design experiments. Such close collaboration helps teachers to rise above being mere experts of content who pass along their expertise to students; they also develop the capabilities to become designers of smart contexts, centering learning activities on students' generated problems, representations, language, learning strategies, and/or solutions. In addition, close collaboration with teachers through authentic, experiential approaches sustained over a period of time has the added advantage of shifting both the teachers' and students' perceptions of learning towards a student-centric educational culture. Thus, our work aims to enhance both theory and practice.

This symposium will be conducted in an interactive format. It will begin with a quick "firehose" session where a presenter of each set of studies/projects shares her/his work in three minutes. Next will be a combined poster/roundtable session where presenters engage in discussions with audience members at their respective stations. Audience members may visit any stations of interest. Moreover, in light of the spirit of SGIs, participants will be offered the opportunity to note their own questions, interpretations, critiques, or ideas on either the general notion of SGIs or on any of the individual studies/projects. During the last segment of the symposium, our two discussants will lead a critical discussion of the presentations, interactions, and audience contributions, and synthesize the salient theoretical and practical crosscutting issues.

Preparation for learning from collaboration by generating ideas

Rachel Lam

It is well understood that simply placing a small group of students together in a classroom does not guarantee effective collaborative learning (Barron, 2003; Dillenbourg, 2002). To encourage students to capitalize on the affordances of collaborating to learn, researchers have examined various instructional interventions such as: teaching students collaboration skills so that students collaborate better (Asterhan & Schwarz, 2009; Rummel, Spada, & Hauser, 2009), scaffolding interactional moves via prompts or scripts to facilitate effective collaboration (Fischer, Kollar, Stegmann, & Wecker, 2013; Walker, Rummel, & Koedinger, 2011), or designing tasks to elicit substantive discussions during collaboration (Engle & Conant, 2002; Kapur & Bielaczyc, 2012). It is apparent that students need support to collaborate effectively for learning, but the best ways to do that remains an open question.

To help students make the most of collaborative learning experiences, we take the approach of designing instructional tasks in ways that invoke effective collaborative mechanisms without directly imposing on student behaviors and interactions. Our task design utilizes a preparation for learning framework, whereby carefully designed preparatory activities promote the cognitive and affective *readiness* to learn from subsequent collaboration. The tasks are grounded in eliciting students' naïve representations relative to the content-to-be-learned by having students freely generate ideas first individually, and then afterward discuss ideas in a small peer group. Our experimental studies conducted *in situ* have shown that compared to learning the canonical representations explicitly and applying them in a problem task, freely generating ideas leads to significant learning gains after collaborating, particularly on transfer items. In addition, the examination of student artifacts produced throughout the learning activity has shown that learning can be attributed specifically to collaborating, only in conditions where students freely generated ideas during preparation. Furthermore, by examining students' discussions, we posit that generating ideas before formally learning concepts invokes preparatory mechanisms to a greater extent, which consequently increases the extent to which collaborative mechanisms are invoked.

During this symposium, I will share our current work on this learning design, which we call Preparation for Future Collaboration (PFC). The design draws from the Preparation for Future Learning paradigm (D. Schwartz), Productive Failure (M. Kapur), and the Interactive-Constructive-Active-Passive ICAP framework (M. Chi). We have been partnering with teachers in Singapore to co-design PFC learning tasks for low-achieving students from the upper primary to secondary levels in various subject areas (environmental sustainability, urban planning, language, mathematics), empirically test our designs in classrooms, and record and analyze student discussions during collaboration. I will offer insights on working with teachers in the Singaporean context, a highly test-driven educational culture within a strong top-down hierarchical education system. To date, our work has been received by Singaporean educators as a "truly student-centered" kind of instruction, yet has also been met with apprehension as teachers shift from their familiar teacher-centric instructional approaches towards instruction based on student-generated ideas.

Investigating the learning and transfer effects of student-generated analogies

Jun Song Huang and Manu Kapur

This presentation expands the Productive Failure learning design (Kapur, 2008; Kapur & Bielaczyc, 2012) by investigating the effects of students generating analogies before receiving formal instruction. The design examines the learning and transfer mechanisms involved in different pedagogical sequences (i.e., generation first or instruction first) and in different forms of analogical thinking (i.e., generating analogies or generating analogical mappings between given analogies).

The design seeks to extend the investigation of the learning mechanisms involved in Productive Failure in two aspects. First, the Productive Failure learning design typically requires students to generate problem solutions during the generation phase. Such activity allows students to recognize their knowledge gaps and

subsequently attend to those gaps at the instruction phase (Kapur, 2014). By investigating generative activities that do not involve problem solving, this work addresses how to design for Productive Failure without orienting towards a problem goal state. Second, through problem solving, the Productive Failure learning design activates and differentiates students' relevant prior knowledge (Kapur, 2014). The patterns of prior knowledge activation and differentiation have been found to be linked to the effects of learning and transfer (Kapur 2014, 2015). Our design question is whether an activity that is targeted to activate and differentiate relevant prior knowledge by providing more degrees of freedom might be better for learning and transfer than an activity that has less degrees of freedom (i.e. is more constrained). To explicate, the activity that requires students to generate analogies (which is more aligned to the conventional Productive Failure generation phase) has more degrees of freedom compared to the activity that requires generating analogical mappings for given analogies. We speculate that student learning and transfer may be enhanced when they are given more degrees of freedom in generation, especially when they generate first before instruction, because this may better activate and differentiate relevant prior knowledge.

We conducted an experimental study to investigate the design. One hundred and twenty seventh-graders in a high-achieving girls' school in Singapore participated in the study. The curricular unit covered how to formulate a system of linear equations for mathematics word problems. Findings partially confirm our hypothesis, with indicators suggesting that generating analogies before formal instruction enacts different learning mechanisms. In this symposium we share our preliminary data analysis that helps to expand the understandings of the Productive Failure learning design.

Addressing the language demands of science using student-generated representations

Lay Hoon Seah

The fundamental role of language in science has been widely recognized over the past decades, encapsulated in notions such as fundamental literacy (Norris & Phillips, 2003), disciplinary literacy (Moje, 2007) and science literacy for all (Yore, 2012). Underlying these notions is the recognition that scientific language has its own specialized features, norms and conventions that distinguish it from language used in other disciplines and in everyday life (Gee, 2004). Research on students' use of language (e.g. Frändberg, Lincoln & Wallin, 2013; Schoultz, Säljö, & Wyndhamn, 2001; Seah, Clarke & Hart, 2015) has also highlighted students' difficulties in interpreting and employing the language of science. A critical aspect of science teaching thus involves attending to and addressing the demands inherent in the use of the language of science. However, while science teachers may recognize the language demands of science, they face challenges in designing lessons that foreground and address the language demands of science in an explicit way (Seah, 2015).

In this study, the researchers worked collaboratively with science teachers to design lessons that took into consideration the language (in addition to the conceptual) demands of science. As with the other studies in this symposium, SGIs was an important component of the lesson design, and in particular, its manifestation in the form of linguistic representations. These student-generated representations played a key role in the lessons in several ways. Firstly, they provided one of the means by which to determine the nature of the language demands and the extent to which these demands needed to be addressed in the lessons. This was achieved by examining the similarities and differences between the student-generated representations and the scientific language during the process of lesson planning and review. During the lessons, these representations became the target of intervention as well as a resource for teaching. For example, teachers highlighted the linguistic differences between the student-generated representations and the canonical use of scientific language to bring about awareness of the language demands of science.

Drawing on a variety of data such as teacher interviews, lesson videos and videos of the lesson planning sessions with teachers, I analyzed the process in which the student-generated representations were utilized across different contexts (before, during and after lessons). The analysis revealed the connections (or lack thereof) that the teachers made among the various roles of these representations, and through this I offer insights into the challenges teachers encountered and share some possible ways for supporting teachers to use student-generated representations effectively.

Makerspaces as sites for studying embodied creativity practices

Michael Tan

While research in cognition has moved into the realm of the sociocultural with the landmark work of distributed cognition researchers, in recent years some attention has returned to the individual as the unit of analysis.

Specifically, the embodied cognition research agenda has started to look at the role of bodily actions and interactions with objects (and to a lesser extent, other humans) in cognitive processing tasks. Essentially, embodied cognition now supposes that actions need to be considered as cognitive if they perform the role of an equivalent process "in the brain." Thought about this way, embodied cognition is a means of spreading the explanatory load for cognitive processes out of the skull, and to the body and beyond (Clark, 2001; Clark & Chalmers, 1998; Shapiro, 2011). This project is a means to explore the role of the body and its material interactions with reality when students learn through the generation of draft designs.

Using this embodied cognition perspective then, an interesting context to study is the phenomena of tinkering; loosely called "thinking with your hands" by design leaders, and widely acknowledged in makerspaces to herald a new way of learning STEM knowledge, skills, and dispositions. Yet, the question remains how to explain tinkering. Specifically, thinking about the phases of design problem solving, two major cognitive processes are ill-structured problem solving, and well-structured problem solving. Taking the geneplore (Finke, Ward, and Smith, 1992) model of creativity, the hypothesis remains that there ought to be two rather distinct roles that actions play in the design and making of artifacts (see, also, Goel, 2014). Given the widely advertised ability of makerspaces to facilitate innovativeness and creativity, I present my preliminary work studying the processes of tinkering in makerspaces.

Students in this study were presented a design prompt to create a device to attract teachers' attention, a collection of magnetically connectable electronics components, and some tools for cutting and joining materials. Six pairs of student volunteers were video-recorded in pull-out sessions of about an hour each, and the actions and talk during their design sessions were examined. Initial analysis indicates: (i) that students do not distinguish between distinct divergent generation and convergent problem solving phases, with more creative designers remaining open to suggestions for improvement throughout the entire design phase; (ii) student actions nonetheless demonstrate two distinct classes, with a higher degree of epistemic action associated with an exploratory phase of their activity even when they did not identify it as such. Implications for further research and practice will be discussed.

Designing for game design

Matthew Gaydos

Game design has been successfully used to introduce students to academic content and skills like programming (Kafai, 2006; Overmars, 2004) as well as so-called twenty first century curricula like digital literacy or design thinking (Games, 2008; Gaskin & Berente, 2011). However, aside from using it as a motivating activity (e.g. Cira et al., 2015), there are not well-tested approaches or frameworks for integrating game design into curricula (for games generally, see Foster & Shah, 2012). This is especially the case when using game design to teach content that is secondary to game production (e.g. biology as opposed to programming).

In this presentation, I describe a design-based research project in which an extensible geography card game is developed for use in Singapore classrooms. The card game is designed to provide students with a game-based model to think *with* as they engage the target content. Once students understand the game model, they may then be able to use it both for understanding other models and predicting outcomes of model perturbation, especially through their own designs (e.g. inventing new rules and cards).

Though these student-generated designs are theoretically useful, they may be impractical within Singapore classrooms, which tend to be oriented toward improving high-stakes assessment results (Chee, Mehrotra, & Ong, 2014; Hogan et al., 2013). Additionally, educational games bring with them a host of logistical challenges (Van Eck, 2006), and may be difficult to use with audiences unaccustomed to game-based approaches (Chee, Mehrotra, & Ong, 2014). The study that will be presented details the contextual factors that support and detract from student-generated game play and design as a pedagogical tool within a high-stakes test-centered system. Through interviews with teachers and students, it focuses on the perceived affordances and challenges of integrating games and game design into the curriculum.

Singapore's Ministry of Education has provided widespread support of game-based learning and other student-centered, technology-based pedagogical developments. Because of the centralized organization of Singapore's education system, there exist few mechanisms for feedback regarding how such policies influence practice or how successful enactments may be spread across sites. Teacher and student feedback is thus not only useful for understanding how these new pedagogical artifacts (including games) may be better developed and used, but provides a means for reflecting on the relationship between policy goals and classroom outcomes.

Seamless learning: Idea generation *from* and *for* cross-contextual learning processes

Lung-Hsiang Wong

Seamless learning is when a person experiences a continuity of learning, and consciously bridges the multifaceted learning efforts, across a combination of locations, times, technologies or social settings (Sharples et al., 2012; Wong, 2015). Despite often being characterized as "anytime, anywhere learning," the notion of seamless learning is however differing from e-learning. "Anytime, anywhere learning" could also refer to flow learning (Csikszentmihalyi, 1990; Sharples, 2015), i.e., to induce a flow state such that learners are so engaged in a learning activity that they lose awareness of their surroundings. Instead, seamless learning foregrounds the unique ecological constructs/resources in various learning spaces including artifacts, tools and people which/who could facilitate multifaceted tasks (Wong, 2015), e.g., the classroom for learning engagement and consolidations, physical spaces for situated and authentic learning, online platforms for information seeking/sharing and peer discussions, etc.

Thus, a holistic seamless learning experience requires learners not only to interact with other people (e.g., peer learners) and instructor-provided artifacts within a relatively closed learning environment (e.g., traditional classroom or e-learning portals), but also with the authentic environment and perhaps the Internet at large, where they may draw elements or information that they incidentally encounter or recall (e.g., building on prior knowledge or past experiences), exploit hidden affordances of *in situ* artifacts, and appropriate the right combination of these elements to "jointly mediate" (Wong, Chen & Jan, 2012) their *in situ* and/or cross-contextual learning tasks. Under such a perspective, learners may generate various forms of "ideas" throughout the learning process, encompassing not only the intermediate or final learner-created artifacts as representations of their current knowledge states, but also the process-related strategies that the learners figure out by themselves to improve their learning process or overcome novel learning problems. In light of this perspective, our team developed an alternative qualitative method known as "artifact-oriented analysis" (Wong, Chen & Jan, 2012), rooted in the Vygotskian notion of "mediation by artifacts" and distributed cognition to unpack the seamless learning process data collected through our studies (e.g., So, Seow & Looi, 2009; Wong, 2013). In a nutshell, as aspirations for lifelong learning, the advocates for seamless learning should entail the fostering of learners' dispositions and skills in self-generating "ideas" to advance their own learning endeavors.

Another important concept of seamless learning that is relevant to SGIs is "recontextualization." Earlier literature tended to dichotomize decontextualization and contextualization in expounding the differences between formal and informal learning (e.g., Hung, Lee & Lim., 2012; Lave & Wenger, 1991), perhaps due to privileging authenticity. We offer an alternative perspective of "recontextualization" (cf. Looi, et al., 2010) of skills, knowledge or meaning through the cross-contextual and cross-temporal learning trajectories. For example, an "idea" incubated in class may be practiced or reified in authentic settings, and later be scrutinized, enriched, transformed and/or challenged within the social learning spaces, with relevant but diversified personal perspectives, knowledge and experiences mediating the socio-constructivist discourse (e.g., Lewis, Pea, & Rosen, 2010; So, Seow, & Looi, 2009). Through such a cross-contextual trajectory, both the "idea" and the learning process itself are constantly "recontextualized," which would lead to deep learning.

Discussion

While the above research projects vary in orientations and research goals, the commonality that stands out among them is the focus on student-generated ideas as a cornerstone of the learning design. Students' ideas play multiple roles in the respective projects (e.g. as a targeted outcome in the development of learning tasks, target for intervention, resource for learning, data source, etc.). These roles can be organized according the cognitive, social and cultural aspects in the design of interventions (Kapur & Bielaczyc, 2012). By leveraging various types of students' ideas in several ways (e.g. as knowledge representations, language, strategies, decisions, design thinking), we offer our collective design principles embedded in the SGIs approach in Figure 1.

Design Principles for Student-Generated Ideas	
Cognitive	
Planning for and leveraging unpredictability...	Eliciting students' naïve representations of yet-to-be learned concepts allows teachers to better understand what students know and can guide their instructional moves accordingly. In order to do that, teachers must become comfortable with planning for the "unplannable," since they cannot know exactly what a student knows until the student shares it.
...by turning student errors into opportunities.	Teachers can oftentimes be quick to correct student errors for a number of reasons: fears that students' errors will "stick," discomfort with uncertainty, aversion to failure, and general habit/familiarity with being the "sage on the stage." However, allowing students to correct their own errors, struggle through failures, and manage uncertainty are powerful learning resources. SGIs provide opportunistic conditions that support students to do the hard work of struggling to overcome their own misunderstandings and to develop their naive representations.
Social	
Capitalizing on student dialogue.	The social opportunities in a learning environment are crucial for designs based on student-generated ideas. Conditions should be set up such that students can engage in natural and authentic conversation. It is not about imposing structures onto social experiences that direct students to discuss "the right things," but creating an atmosphere through the learning design that promotes the curiosity and motivation to talk through ideas, thoughts, and decisions with one another.
Cultural	
Perceiving ideas as a "means" and not an "end."	Although helping students to generate their own ideas in the first place is a noteworthy goal, the intent of SGIs is rather to use students' ideas as the means for (a) the student to improve understanding and meaning-making and (b) the teacher to facilitate the student learning process by basing instruction on the students' own representations. Students and teachers may not be initially comfortable with this perception and process, and so a classroom culture that supports SGIs may need to be developed.

Figure 1: Design principles for Student-Generated Ideas.

With student ideas at the forefront, our collective work addresses how approaches based on SGIs influence the learning mechanisms, knowledge outcomes, and socio-cultural surround in authentic settings. SGIs involve a process of ideating, e.g., through the generation of solutions/problems, elicitation of language, invoking "design thinking" through play and embodied experiences, and removing the "seams" of learning from the classroom to the informal environment. This symposium not only aims to fill gaps in the knowledge base, but also plays an active role in progressing the cultural shift towards student-centric instruction. Through distilling and sharing the core design principles around SGIs-focused learning approaches, this work contributes to important components to the learning sciences discipline and in changing educational practice.

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Acknowledgments

Moving Ahead in the Study of STEM Interests and Interest Development: A New Research Agenda

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Abstract: We seek to jumpstart a program whose long-term goal is to advance a more nuanced and encompassing understanding of STEM interests by comparing and contrasting how they are manifested across settings of STEM practice. People can and do get interested in STEM-based activities in the various spaces in which they encounter these activities—e.g., the home, museums, hobby fields, school, and after-school programs. However, because each such setting operates under different constraints and affordances, the forms of interest-based participation they spawn and support are qualitatively different. This symposium brings together four distinct research projects, each of which addresses very different settings, aspects, and phenomena in people's interest-based participation in STEM. The projects also deploy very different methodologies to document and measure people's interests. By comparing and contrasting these very distinct takes on interests and their manifestations across settings, we gain insight into both generalities and context specific aspects of interests and their enactment.

Symposium goals

Heeding ICLS 2016's focus on "Transforming learning, empowering learners… to design their social futures," this symposium addresses central, yet little understood aspects of learning processes—namely, the functioning of interests and their development over time, especially in and around STEM domains and disciplines (e.g., Renninger, Nieswandt, & Hidi, 2015). Short- and long-term interests have long been recognized as essential factors mediating how, when and what one learns in an activity (Dewey, 1913; Krapp, Hidi, & Renninger, 1992). The centrality of interests for learning processes is further foregrounded when we consider the lifelong and lifewide character of learning (National Research Council, 2009). Empowering learners must therefore include mechanisms to support them in the earnest pursuit of their interests, emergent and long standing.

For historical, practical, and methodological reasons, however, progress in the field has been slow to obtain—say, relative to advances in theorizing discipline-specific learning processes (e.g., Smith, diSessa, & Roschelle, 1993/1994) or the socio-cultural foundations of learning (e.g., Lave & Wenger, 1991). In particular, we note that the nearly exclusive focus on interest-based learning and phenomena in classroom contexts has produced theorizing that lacks generality and texture—a point made by Weiner (1990) more than two decades ago. To be sure, we have progressed much since then, but we contend that a more expansive and inclusive research agenda could offer new theoretical, methodological, and practical insights onto interest-related phenomena and spur renewed investigation in the field. For example, recent research in the learning and cognitive sciences has shown that interest-based participation may take on a very different character across contexts and timescales of practice (e.g., Barron, 2006; Bricker & Bell, 2014; Lee & Drake, 2013)—phenomena still not well understood or documented.

Based on these observations, this symposium seeks to jumpstart a program whose long-term goal is to advance a more nuanced and encompassing understanding of STEM interests by *comparing and contrasting how they are manifested across settings of STEM practice*. Building on the collective insights of the literature, we know that people can and do get interested in STEM-based activities in the different settings (e.g., the home, museums, hobby fields, school, and after-school programs) in which they encounter these activities (NRC, 2009). However, because each respective setting operates under different constraints and affordances (e.g., institutional, material/infrastructural, and time demands), the forms of interest-based participation they spawn and support must differ at some fundamental level. Put differently, STEM interests are expressed in *qualitatively different forms* depending on the settings and practices in which they are embedded. By comparing and contrasting different

"versions" or manifestations of interests (and related phenomena) across such settings, therefore, we gain insight into both generalities and context specific aspects of interests and their enactment. Our central goal here is to illustrate this approach, as we explain next.

Goals and structure, elaborated

In line with the arguments above, this symposium brings together four distinct research projects, each of which addresses very different aspects of people's interest-based engagement in STEM. The individual projects investigate a broad range of STEM practices and learning settings—specifically, and in order of presentation, an all-girls STEM-centered after-school Maker program, the fields of amateur astronomy, school-based STEM activities, and a large-scale, alternate reality game (ARG) that was played across a variety of online and social media platforms. By explicitly drawing on this diversity of settings, we seek to illuminate dimensions and phenomena of interest-based participation that might otherwise stay hidden (e.g., in institutional, disciplinary, and other structural arrangements) and to bring new light on the relationship among these phenomena.

Fittingly, the individual presentations also deploy widely different methodological strategies to gain access to, and to analyze the interest-based phenomena under study. These methodologies include long-term ethnographies, assessments and scale development, and descriptive analytics of trace data from digital gameplay, among others. This methodological plurality further informs us about the diversity of interest-related phenomena and the equally diverse ways of capturing those. Grounding the symposium, each presentation will explicitly highlight interest-related phenomena—observed or otherwise inferred, through various methods—that "appears" in their data. Taking these as departure points, Dr. Phil Bell, our discussant, will then begin (1) the task of comparing and contrasting these phenomena and broader results, and (2) highlight areas of intersecting and diverging results, thus revealing interests' versions/manifestations across contexts. In doing so, Dr. Bell will also bring in his own extensive work on various settings of out-of-school STEM learning and the forms of engaged participation they foster. This will set the frame for audience participation and questioning.

Wearing their feelings on their sleeves? Wearable technology and the capture of student engagement with Maker activities

Victor R. Lee and Ryan Cain, Utah State University

Project description

The goal for this project, in partnership with a youth-focused community makerspace, has been to interrogate the popular assertion that participation in "Maker" activities establishes "interest in STEM, the arts, and learning as a whole" (Dougherty, 2013, p. 14). Capitalizing on some of our existing awareness of new wearable technologies that can be productively used to support and study learning environments (Lee, 2015), we sought to leverage these new technologies to help us capture and characterize conditions that trigger interest and associated phenomenology of high student engagement in Maker activities. While interest and engagement are different, albeit related constructs, we focus on engagement as the observable indicator of interest, as it can be determined using psychophysiological measurement of electrodermal activity (EDA).

Theoretical framework

This study is informed by both Hidi & Renninger's four-phase model of interest development (2006) and by a growing body of learning sciences research on interest that has highlighted complexities of how interests are manifested *in situ* when participating in out-of-school discretionary activities (Azevedo, 2011; Barron, 2006). With respect to the former, we are concerned with the initial moments of triggered situational interest (Phase 1) that are thought to serve as a basis for the development of a sustained and well-developed individual interest (Phase 4). From the latter, we seek to be attentive to the diversity of possible manifestations of interest that could emerge among multiple individuals in the same environment and under similar material conditions. In terms of Maker practice, this means that we may expect some activities can be broadly interesting for a group of youth because they are novel and promote engagement. At the same time, we do not expect all triggers to be the same for all students. As we discuss below, dramatic changes in setting can be generally engaging for multiple students. On the other hand, opportunities to use new technologies may trigger engagement for some, as is the case for one student who was more engaged with her own sensor testing while her partner had different triggers.

Methods

We have been using two new wearable technologies: EDA bracelets and wearable still-image cameras (Figure 1). The EDA bracelets, Affectiva Q sensors, are wearables that send electricity between two contacts on the wearer's

skin and detects changes in EDA. Initial research on their use suggests they can capture changes in conductance that correlate well with those accepted as among the best in psychophysiological research (Poh, Swenson, & Picard, 2010) but allow the wearer to be mobile and active. The cameras are Autographer wearable cameras, which automatically capture multiple still images each minute from the wearers' point of view. These devices were provided to four adolescent girls participating in a 15-week atmospheric science-themed afterschool maker camp, who wore both devices throughout each camp session.

We note in our presentation there are some inherent challenges with relying too heavily on data from wearables. Namely, changes in EDA reflect changes in arousal, which is associated with increased attention and emotional engagement, but can be positive or negatively valenced. Additionally, parsing EDA data is challenging in that it requires a substantial amount of manipulation as 160 data points are created per minute and base skin conductance naturally changes gradually over time. Also, EDA is typically measured in controlled lab settings where relationships between stimuli and EDA can be directly tested. We have been developing algorithms to help detect when there has been a clear change in arousal and then seeking regularities in actions depicted in the still images given the known challenges. These challenges we consider insurmountable, and the potential payoff of capturing individual and group interest in situ makes this worth exploring. We have obtained third-person video of each session to help us verify and triangulate inferences from the wearables.

Figure 1. The combination of time-stamped wearable still-image and EDA data sets enable the capture of youths' perspective of what they are seeing and doing that has triggered immediate engagement.

Results and implications

To date, we have begun to see instances of regularities of triggers among youth and have amassed evidence of activities and experiences in Maker spaces that yield high and low levels of arousal. For instance, two girls who worked together on assembling a sensor both seemed to exhibit high arousal each time they were asked to change physical settings. Yet there appeared to be moments that were more uniquely engaging to one student rather than the other. One of the two girls appeared to have increases in engagement each time she was testing her assembled sensor. As a contrast, this same girl also had lower level of engagements when running information searches on one of the Makerspace-provided laptops. In our presentation, we will discuss what findings like these suggest to us about engagement in Makerspaces across and within individuals and how these methods could give us some headway to understanding interest dynamics in such a complex physical setting.

The role of fascination and values in developing science career interest

Rena Dorph and Matthew A. Cannady, The Lawrence Hall of Science, University of California, Berkeley

Project description

The purpose of this presentation is to explore the degree to which learners who are fascinated by natural and physical phenomena and/or value science in everyday contexts are more likely to identify these areas as a possible career fields while in their middle school years. We will explore the role of each these constructs separately as well as how they may interact in order to understand if either of them are more influential drivers of science or engineering career interest.

Theoretical framework

Fascination with natural and physical phenomenon refers to the emotional and cognitive attachment/obsession that the learner can have with science topics and tasks that serve as an intrinsic motivator towards various forms of participation. This dimension includes aspects of what many researchers have referred to as curiosity (Litman & Spielberger, 2003), interest or intrinsic value in science both in and out of school (Hidi & Renninger, 2006; Osborne, Simon, & Collins, 2003; Hulleman & Harackiewicz, 2009), and mastery goals for science content (Ames, 1992). It also includes positive approach emotions related to science, scientific inquiry, and knowledge. Past research has found that each of these constructs to be associated with choice towards, engagement during, and attainment in science learning (Hidi & Renninger, 2006; Hidi & Ainley, 2008). As a whole, we hypothesize that fascination is an important driver towards career interest.

Valuing science refers to the degree to which learners value the knowledge learned in science, the ways of reasoning used in science, and the role that science plays in families and communities. In addition, in a young person, valuing science may express itself as both everyday value and career value (Hill & Tyson, 2009). A learner can understand various interactions of self with science knowledge and skills and places value on those interactions within their social context (Eccles & Wigfield, 2002; Osborne, Simon, & Collins, 2003). Those who value science and the role it plays—both in their own lives and in society—are more likely to engage in learning science in and out of school whether or not they find it fascinating (Eccles, 2005; Lyons, 2006). Hence, like fascination, valuing science is also an important motivator towards success in science learning and science careers.

Methods

The analysis draws upon both qualitative and quantitative data sources collected as part of the research efforts of the *Activation Lab* (www.activationlab.org). Interviews about science fascination, value and career interest with 16 middle school students were analyzed to understand the degree to which young people's thinking about career interest is related to their fascination with natural and physical phenomena and the value they place on the scientific enterprise. In addition, analyses of survey data (fascination scale, values scale, and STEM career interest items) collected from a longitudinal study of over 1,500 6th and 8th graders drawn from multiple, diverse schools within two regions in the US was conducted. In particular, we examined models predicting growth in each construct and the relationship that growth had with changes in career interest.

Results and implications

Data analysis revealed that both fascination and everyday valuing of science are related to STEM career interest in middle school-aged youth. Observations of, and interviews with, youth participating in school-based science learning environments reveal that youth who indicate interest in a science-related career are also more likely to either express fascination with the natural or physical world and/or to clearly articulate the value of science for society. Examples of the ways youth express fascination include: expressing interest for particular science ideas or activities exclaiming how "awesome" a particular activity is. Examples of how youth articulate "valuing science" include expressing the role that science plays in improving people's lives through "inventing things that help people," "discovering cures for diseases," and "solving important problems."

Next, we note that survey measures of both fascination or valuing science and career interest are significantly correlated to one another above and beyond relationships with demographics, science competency beliefs, or other variables of interest. Further analysis is underway to reveal how fascination and values interact, to understand if either of them are most influential as a driver of career interest, and to learn for whom and under what conditions each of these constructs is a more influential driver of career interest.

Further, we find that youth across a variety of learning environments (school-based, summer camps, after-school, etc.) who report higher levels of fascination and valuing of science (i.e., science writ large, not a specific domain) have higher levels of engagement in their specific science learning environment. That is, being fascinated and valuing science as a subject seems to position youth to be more likely to engage in a science learning environment regardless of setting (formal vs. informal) and specific science content. We thus see the support that fascination and valuing of science provides manifest in the ways youth build and rely upon a science identity and personal engagement in science learning activities.

The interest-centered pedagogy of amateur astronomy practice

Flávio S. Azevedo and Michele J. Mann, The University of Texas at Austin

Project description

Hobbies are widely seen as prototypically interest-driven practices (Krapp, Hidi & Renninger, 1992; diSessa, 2000), and studying how they structure teaching and learning opportunities can provide us many lessons regarding the nature of interests and how we might effectively design for truly interest-driven engagement. We focus on the practice of amateur astronomy as empirical ground and rely on long-term ethnographies of astronomy practice to capture the richness of interest-based participation and its phenomenology, and the learning that takes place in it.

Analytically, we approach this material from the perspective of *pedagogy* and investigate how teaching/learning events seem to be systematically structured in the hobby, across short and long term pursuits. To be sure, there are many competing models and definitions of pedagogy. Our larger goal is to contribute to this debate by mapping out the essential aspects of the pedagogy of amateur astronomy practice and thus to begin illustrating what pedagogies for interest development might look like. In the spirit of the symposium, we will link these issues directly to the phenomenology of interest-driven participation observed in the hobby.

Theoretical framework

The theoretical framework guiding our inquiry has two major components. First, we draw on *lines of practice* theory (Azevedo, 2011, 2013) to frame how we look for aspects of pedagogy in a hobbyist's pursuit of the practice (amateur astronomy, in this case). A line of practice describes a specific set of medium- to long-term activities in a person's pursuit of a practice of interest. Any practitioner pursues multiple parallel lines of practice, each of which reflecting a person's unique *preferences* in the practice, and preferences are continuously attuned to the *conditions of practice* imping on one's hobby (e.g., access to resources such as literature, telescopes, sites of practice, and more competent peers). The point to observe is that practitioners learn along their tailored lines of practice and therefore following these processes of learning shed light on the phenomenology of interests and their pedagogical significance.

The second major component of our framework regards a particular lens into the nature of socio-cultural practices and their organization, and a consequent understanding of when and how teaching/learning occurs. Traditionally, we have associated learning with direct acts of teaching. Given the interest-based nature of hobbies, however, we decouple learning from teaching (Lave & Wenger, 1991; Stevens, 2000) in order to: (1) allow for the possibility of a pedagogy of (partially) self-teaching, which is ubiquitous in amateur astronomy (and other hobbies); and (2) to capture the fluid arrangements of teaching and learning that happened at short timescales of collaborative field practice.

Methods

We draw from two different studies, both long-term ethnographies (Hammersley & Atkinson, 1995) of amateur astronomy communities, spanning a total of 3 communities/clubs and several individual astronomers as cases studies. The first study was carried out by the first author between the years of 2002 and 2003 and it included two communities in Northern California. Briefly, the study sought to capture practitioners' patterns of long-term, interest-based participation and how these emerged in the interactions between practitioners and the larger spaces of practice that they frequented. In the second study, throughout the year of 2014 we followed a community of amateur astronomers who met regularly at the High Meadows site in the Texas hill country. This time we were specifically concerned with documenting teaching and learning events and how they came about, and particularly how embodied cognitive practice played out in observational amateur astronomy. Overall, we collected more than 15 hours of videotapes and several pages of field notes and analytical and theoretical memos.

Results and implications

In presenting our results, we comb through our ethnographic records in search of teaching and learning interactions—across a range of timescales—and list their associated phenomenology. For each of these, we then draw inferences regarding the explicit or implicit aspects of pedagogy involved:

1. Phenomenology: Participating in peers' activities. During collective field practice, it is not uncommon for an astronomer to be "absorbed into" other participants' own observational goals and activities.

   Pedagogy: Unintended, serendipitous learning/teaching of content that prepares for future pursuits; interactions strengthen relationships. Occasional encounters with astronomy practices (say, in a visit to a museum) lead to similar results.

2. Phenomenology: Reading at home and explicitly formulating learning goals.

   Pedagogy: While learning goals are prominent in amateur astronomy, they are not the sole or even most important goal that practitioners nurture. Still, astronomers routinely engage in self-teaching by reading various specialized literature.

3. Phenomenology: Fluid switching of teaching roles. In the common collaborative pursuits that emerge in field practice, relative novices routinely teach some content to more experienced peers.

   Pedagogy: Legitimate peripheral participation (Lave & Wenger, 1991).

4. Phenomenology: Pursuing themed observational lists. Organized, themed lists of observational target are deeply shared within and across amateur astronomy communities (and indeed the hobby as a whole).

   Pedagogy: Lists constitute the emergent and more stable curricula that serve to structure long-term, self-paced, interest-based engagement.

As we advance in our analysis, we will add many more elements to this list and thereby increase the space for cross-comparisons analyses of setting-specific interest-based participation.

Fascination, self-competency beliefs, and expressions of play in an alternate reality game

June Ahn, University of Maryland, College Park

Project description

Alternate reality games (ARGs) ask players to assume roles as characters in an interactive fiction. ARGs are played across multiple platforms with puzzles and activities that are distributed across social media, books, video, and real world environments (Bonsignore et al., 2012, 2013). Our research team has been designing and researching the potential for ARGs to promote informal science learning for youth. Our first ARG called DUST, in collaboration with NASA, launched in January 2015 and garnered over 2,000 registered players. The story of DUST revolved around a group of diverse teenagers, who witness a meteor shower at a NASA facility. All of a sudden, the adults collapse, unconscious, and it is up to the teenagers of the world to solve the mystery and save humankind. The story is told over time, through graphic novels, and teen players utilize online platforms to pose questions, theories, evidence, and notebook reflections (QTEN) to collaboratively research and solve the mystery. We detail the complex design challenges of DUST to authentically integrate scientific inquiry with gameplay (Pellicone et al., forthcoming). Furthermore, our emerging work attempts to take log data from DUST platforms, and use various data analytics to understand players' choices for play within the designed environment of the ARG.

Theoretical framework

Azevedo's (2011, 2013) work on *lines of practice* inform our exploration into interests and its expression in designed game experiences such as ARGs. First, it is important to know that learners come to a given learning experience with existing *preferences* for practice and sense of self. We focus on two concepts – fascination and self-competency beliefs – that may characterize one's preferences for practice (Crowley, Barron, Knutson, & Martin, 2015; See Dorph and Cannady in this session). To engage in a practice, one must have some level of fascination about some aspect of the activity and also have some level of belief that they can participate in the activity. In DUST, players bring different levels of fascination and self-beliefs about their ability to engage in the scientific inquiry practices that comprise the ARG.

Second, the features of a material environment may allow or constrain the expression of these preferences, and through activity, further deepen these lines of practice over time. Thus, players' fascination and self-competency beliefs may then intersect with the kinds of activities that were explicitly designed in the ARG. For example, in DUST players had to forward the interactive narrative by posing questions, forming theories, and finding and arguing for their theories with evidence. Players could also do a variety of other activities including network with friends, collaborate on tasks, and discuss ideas. Taken together, we aim to examine whether and how prior levels of fascination and self-competency beliefs relate to the diverse ways that players can appropriate the different designed-experiences in an ARG.

Methods

DUST was an entirely open, informal experience. Through various recruitment efforts, over 2,000 players joined DUST. When players registered, we collected demographic data along with measures of fascination and self-competency beliefs in science (see Dorph & Cannady, this session). The various online platforms that players used to debate their QTEN contributions also were instrumented to record detailed, time-stamped logs of player activity. This data collection effort motivates various analytic strategies to better understand how learners came to, and experienced DUST, over time. We will present two facets of our preliminary and emerging work (1) our efforts to construct variables of game activity from log data and (2) how these measure of activity relate to learners' fascination and self-competency beliefs in science.

Results and implications

In this presentation, we will present our initial data analysis on player demographics of our teenage players (n=1,027), and descriptive analysis of the fascination and self-competency belief measures. We also began constructing measures of game activity, thinking about the designed affordances of DUST. For example, we created counts of the core QTEN activities that were integral to creating the interactive narrative in DUST. Players could also network and "friend" other players in the game, which allowed us to create social network graphs and counts of how many others a player was connected to. We will present various visualization techniques used to explore the data to understand how individual players contributed QTEN posts.

In addition, we explore the relationship between fascination and self-competency beliefs with these patterns of contribution (Table 1), which begins to illuminate new avenues for inquiry. For example, fascination and competency beliefs were correlated with all types of QTEN activity but not friendship activity. In addition, there are intriguing relationships for further exploration between types of contributions. For example, in our qualitative data and interviews with players, we found that some players who did not feel confident enough to contribute QTE's – perhaps feeling that these were high-barrier scientific practices requiring expertise – often stated that they preferred instead to post free-form "notebook" posts. However, we saw in our data that posting of notebook posts was also correlated with posting questions, theories, and evidence. Could certain modes of game contribution, say notebook posting, appeal to certain players (e.g., who feel less competent in science to begin), but be a gateway to other expressions such as engaging in theorizing, questioning, and arguing from evidence? Building from these preliminary examples, we will present various ways to use analytics to better understand these relationships between facets of interest and the developing expressions of players' game activities through the designed affordances of DUST.

Table 1: Correlations between Activation Scales, Friends, and QTEN contributions

	Fascination	Self-Competency	Friends	Question	Theory	Evidence	Notebook
Fascination	1.0						
Self-Competency	0.69*	1.0					
Friends	-0.07	-0.06	1.0				
Question	0.23*	0.14*	0.20*	1.0			
Theory	0.23*	0.20*	0.20*	0.57*	1.0		
Evidence	0.16*	0.15*	0.35*	0.57*	0.53*	1.0	
Notebook	0.15*	0.13*	0.31*	0.22*	0.33*	0.38*	1.0
* $p < 0.05$							

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Fostering Deliberative Discourse in Schools Towards the Constitution of a Deliberative Democracy

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Abstract: This symposium focuses on forms of classroom discourse that have the potential to lead to societal change. The deployment of these forms of discourse that we designate as deliberative discourse provides unique moments during which a communicative rationalization is realized. We present very different programs in civic education, science, philosophy or history that realize this communicative rationalization. The common denominator of these programs is that they all provide long-term learning experiences. Through iterative enactment of collaborative inquiry and/or argumentative moves, students acquire norms that prepare them for the constitution of a deliberative democracy.

Introduction

35 years ago the German philosopher Jürgen Habermas faced the critique of subject-centered reason initiated by Nietzsche and forcefully expounded by the post-modernist movement. Habermas vision of communicative rationalization was further developed by Amy Gutmann as the ideal of deliberative democracy. They saw in argumentative forms of discourse, in which power relations could be made visible and contested, the realization of communicative rationalization.

Engaging students in joint reasoning and resolving of disagreements through argumentation have gained increased attention in education (Schwarz & Baker, 2016). Accumulating evidence shows that structured and socially supported argumentation can produce substantive learning gains in many school subjects and in general reasoning (Resnick, Asterhan, & Clarke, 2015; Wegerif et al., 1999). However, in this symposium, we go beyond the productivity of social argumentation in terms of learning gains to investigate whether and how classroom discourse can realize democratic participation, or in Gutmann's terms instantiates moments of deliberative democracy. In particular, the symposium asks: How can deliberative democracy be conceptualized as a form of classroom discourse? How can deliberative discourse be fostered in school education?

This symposium argues that, unfortunately, in democratic education, a lack of attention to the structuring of social interactions between teachers and students has crucially contributed to a failure of schools to engage students in democratic participation. For example, interaction in school democratic meetings are regularly dominated by a 'control discourse' that effectively delimits students' possibilities to voice opinions and suggestions outside a predefined agenda (e.g, Thornberg, 2010). We will delve into the actual forms of talk that are at the same time productive in terms of learning gains and that realize the ideals of deliberative democracy. Moreover, the symposium argues that deliberative democracy can be fostered in schools by giving students opportunities to engage with complex and controversial topics characterizing democratic social life. Opening up spaces to engage with uncomfortable, current and historical issues triggers emotionally-loaded discussions that, with adequate tools, can potentially be turned to valuable learning experiences.

The five symposium contributions will shed light on how schools can function as sites of deliberative democracy through promotion of diverse forms of deliberative discourse. *Rosé and Clarke* discuss the problem of deliberative democracy in terms of providing students in low-performing urban schools access to a specific form of deliberative discourse, Accountable Talk, in which accountability to reasoning and to knowledge is counterbalanced by the accountability to the other (Michaels, O'Connor, & Resnick, 2008). Rosé and Clarke seek to tackle this problem by instilling Accountable Talk in science education. They developed teachers' use of Accountable Talk as well as series of student-level interventions designed to prepare students to engage in the whole group teacher-led discussions in online CSCL activities and face-to-face activities. *Tammi and Rajala*

illuminate how what counts as deliberative discourse can be renegotiated in unfolding classroom interactions between students and teacher. They present a program that sought to foster deliberative discourse in democratic classroom meetings. They show how the rules of classroom discourse shifted from rules that stress the teacher's authority to more democratic rules. They also show how deliberative communication led to democratic decision making. *Fynes-Clinton and Renshaw* focused on a multicultural school community that participated in collaborative philosophical inquiry (CPI). CPI has been established as the pedagogical method that underpins all curriculum planning, development and implementation at the school. Although the involvement of students in CPI created a more democratic culture in the school, Fynes-Clinton and Renshaw show that inquiry was first based on "paper doubt" rather than on "genuine doubt" where students are authentically engaged in open-ended inquiry for an extended period of time. These expressions of genuine doubts in collaborative inquiry are discussed as expressions of democratic deliberation.

Solli, Hillman, and Mäkitalo bring democracy at a place which is generally reserved to elite: scientific controversies generated by technoscientific innovations in a world that relies heavily on digitized information. They show that students can engage in deliberative discourse addressing scientific, societal, ethical and cultural perspectives in issues such as global warming, by using digitized information. The collaborative mapping of these controversies involving tools for navigating support students' engagement in complex issues. *Schwarz and Goldberg* create dialogue spaces in history in a multicultural context on hot issues that usually exacerbate divergences among discussants. Through on-line discussions, Arabs and Jews discuss controversial issues about Modern History of Israel. They show that through a meticulous design, they can harness emotions to productive deliberative argumentation. The fact that deliberative discourse is sustained in long-term learning experiences on very hot historical issues that generally divide these groups indicates that the students are ready for the constitution of a deliberative democracy in a country with presently conflicting identities.

Finally, *Wegerif* provides his reflections on the topic and opens the discussion.

Fostering a culture of active deliberation through accountable talk

Carolyn P. Rosé and Sherice Clarke, University of Pittsburgh

A culture of active deliberation would be one in which students own their reasoning, and thereby see themselves as sources of knowledge and insight within a community of other reasoners. As reasoners within a community of reasoners, students would value both their own reasoning as well as the reasoning of others. A discourse culture of this kind is ripe for inducing cognitive conflict, which can create opportunities for self-reflection and cognitive restructuring. In our story, teachers play a guiding role, but students are the key agents of change. And technology serves as a catalyst for change. We report on a longitudinal teacher development study with the goal of supporting teachers in their work to embed active deliberation through talk in urban schools.

There is growing evidence that teachers can play an important role in fostering and supporting a classroom culture of active deliberation. Specifically, when teachers lead students in classroom discussions where the goal of talk is collaborative sense-making about subject matter, and students are positioned as 'knowers' within these discussions, students benefit in terms of steep increases in learning, long-term retention, transfer across subject matter and the development of reasoning (Resnick et al., 2015). Yet, we find that some populations never get access to the kind of active deliberation that grows the mind and society (Oakes, 1990; Kelly, 2008). Thus, the ideal of deliberative democracy is largely unrealized where it concerns populations of the highest need, e.g., students in low-performing urban schools. In this symposium talk we report on several studies embedded within a five-year longitudinal project that sought to disrupt this pattern by embedding Accountable Talk (AT) in science instruction in an urban school district (Michaels et al., 2008).

In our work, we sought to target populations of teachers that were not yet experts in AT, and work towards developing their use of AT discourse moves. Likewise, we focused on student populations that have not otherwise experienced rich discursive instruction. We conducted a longitudinal design study in an urban school district that had failed to meet national standards for achievement on standardized tests for 5+ years.

The teacher-level intervention focused on developing teachers' use of AT in whole class discussions through professional development workshops and one-on-one coaching. Training focused on how to embed AT in their curriculum, plan a discussion, and engage in AT simulations. In addition to the teacher-level intervention, we developed a series of student-level interventions designed to prepare students to engage in the whole group teacher led discussions. Some of these activities were online CSCL activities focused on collaborative inquiry, while others were face-to-face activities focused on developing reading comprehension skills. We expected these activities to increase student responsiveness to attempts by the teacher to engage them in active discussion and therefore serve a reinforcing effect of the teacher-level intervention. Each of the CSCL interventions were themselves experimental studies (e.g., Dyke et al., 2013; Clarke et al., 2013)

The guiding role of teachers is highlighted in a study of student agency in teacher led whole class discussions. Here we took an in-depth examination of student participation in these discussions to unpack the nature of students' agency (Clarke et al., 2016). Examining the classroom discussions at the turn level to understand what gives rise to students' participation, we found a pattern whereby if a student exercises their agency to participate in discussion, the teacher solicits that student to participate again later in the discussion, and vice versa. This finding suggests a dynamic duality of student agency in discussions: students are responsive to the teacher's guidance, and teachers are responsive to students' agency in discussion. So while students may have general profiles with respect to their participation in discussions (e.g., high participators and low participators) and enacted agency (i.e., highly agentive and marginally agentive), students' sense of agency is not a stable. Students require some support.

While this story suggests an essential role for instructors to keep the discussion active, a further analysis provides evidence of the extent to which even the teacher's behavior is supported by the agency taken by students. Here we recount an analysis of teacher growth in AT appropriation in the experience of one instructor with several of his classes. The students participated in online small group activities facilitated by intelligent conversational agents several times in Years 1 and 2, immediately prior to a teacher-led whole class discussion on the diffusion and Punnett Squares respectively. A conversational agent-as-facilitator must be able to manage several differently-scoped supports and behaviors concurrently. In all three studies, students worked in groups of three to make predictions, discuss observations, and generate interpretations of their observations. Intelligent computer agents supported student groups providing a macrolevel structuring of the task and some level of micro-level support, which in some cases included AT facilitation moves. Across the three studies, we found positive effects on student learning of the agent that engaged in AT facilitation (Dyke et al., 2013).

The most striking result was the effect of the students (returning to the classroom after these activities) on the teacher facilitation of AT. Using growth modeling techniques applied to a series of 57 transcripts coded for the prevalence of AT using an automated technique, we determined that teacher growth was very slow over time, but a spike in uptake of AT was concentrated in lessons immediately following collaborative activities, with an effect size of 1.7 standard deviations. We concluded, that the scaffolding for students' AT in the CSCL environment had an impact on how the teacher intellectually positioned students in the subsequent discussion. Thus the technology served as a catalyst for change and the students as agents of change in the discourse culture of these classrooms.

Thus, students can play a particularly important role in shaping the discourse culture of classrooms towards deliberative, if the teacher creates an opportunity space for students to enact agency in discussions. We count the technology as a catalyst for change, as our evidence shows that intelligent agent support in group activities had a facilitative effect on students' active deliberation in subsequent discussion.

Fostering deliberative communication in democratic classroom meetings

Tuure Tammi and Antti Rajala, University of Helsinki

Research in the learning sciences has established that the structuring of classroom interactions has a significant impact on students' learning (e.g., Resnick et al., 2015). Some research goes further to suggest that guiding students in using talk as a tool for reasoning not only supports their academic learning but can equip them with resources necessary for democratic participation (Michaels et al., 2008). Yet, empirical research on naturally occurring classroom interactions during school democratic meetings shows that the structuring of these interactions counteract attempts to engage students in democratic participation (Thornberg, 2010). These interactions have been characterized as 'control discourse' that feature the teacher controlling the classroom interactions through limiting the students' possibilities to pose questions and through evaluating their responses.

In this presentation, we put the research on deliberative democratic education into dialogue with the research on academically productive talk (Wegerif et al, 1999). We will demonstrate how teachers and researchers can change classroom interactional patterns to foster deliberative communication and democracy. *Deliberative communication* not only involves active listening and resolution of disagreements through argumentation, but also allows the questioning of authorities and conventional views (Englund, 2006). We zoom in on the interactions of one fourth-grade classroom in Finland in which the researcher and the teacher had conducted an intervention to foster deliberative communication over three school terms (2008-2009). We ask: Can deliberative communication be introduced in an elementary classroom? How does the introduction of deliberative communication contribute to students' opportunities to engage in democratic participation?

The intervention was based on action-research methodology through which material artifacts and interactional norms were negotiated with the class. First, the students could communicate their suggestions and initiatives and suggest a format for dealing with these. Second, time was allotted weekly to discuss and decide on

the issues to be dealt with collectively. Third, ground rules for talk were negotiated with the students, following the procedures based on the Thinking Together program (Wegerif et al., 1999), which is a method for fostering academically productive talk. Fourth, the chosen issues were dealt with in the chosen format.

The data for this presentation comprise the video recording of one deliberative meeting in which the class was negotiating and deciding on what to do for a field trip. We decided on the basis of our preview of the videos and earlier analysis of the data that this particular discussion, which occurred in the last meeting recorded in the data set, constituted a rich case illustrating the enactment of deliberative communication in this classroom. The analysis proceeded as follows. First, the video recording was transcribed. Second, to create an overview of the nature of the classroom interactions during the meeting we coded each speaking turn with respect to who was the speaker (teacher/student) and what was its interactional function. Third, we conducted a qualitative interaction analysis of the classroom interaction by comparing its features with the criteria for deliberative communication that emerged from our review of the theoretical literature on the topic. In particular, we paid attention to references to the ground rules for deliberative communication negotiated with the students as part of the intervention. Fourth, we carried out a thematic analysis of the contents of the classroom talk to identify any connections with the students' opportunities for democratic participation.

Our findings show that establishing and negotiating communicative ground rules fostered a shift in the pattern of classroom interaction that enabled the emergence of deliberative communication. Our analysis of the interactions indicated that the students had become acquainted with deliberative discursive norms, and these norms were put into practice to explore personal experiences and interests and to draft collectively acceptable conclusions. The students built on each other's views either by supporting them or constructively refuting them. Disagreements were resolved through argumentation. Moreover, our findings indicate that the introduction of deliberative communication provided the students with new opportunities for democratic participation. Firstly, the students could not only evaluate, support and question each others' views, but also those of the teacher. Like the students, the teacher was also made accountable to the communicative ground rules. Secondly, through deliberation the class explored their relations to social practices in and out of school and made visible the ways in which the broader social conditions posed constraints for them and on the decision making. Thirdly, the students did not only debate the topic but also the way the decision making process was unfolding. Consequently, the decision making was made transparent instead of being treated as given by the authorities or as being beyond alternatives (cf., Thornberg 2010).

There is great potential in democratic classroom meetings to create space and time for students to explore, debate and take action on issues they consider important. The relevance of these discussions reflects the fact that they may help students (and teachers) to reflect upon the complexity inherent in the lives of different people regarding common issues, as well as to question and redefine how they relate to social practices in and out of school. From this perspective, democratic education is not reduced to the provision of knowledge, skills and dispositions, but is a site for the development of political ways of being, doing and seeing that transcend predefined and reproductive categories of what it means to be a student, a teacher or a citizen.

Genuine doubt and collaborative philosophical inquiry: Towards a more democratic school culture

Elizabeth Fynes-Clinton and Peter Renshaw, The University of Queensland, Australia

This paper draws upon an extended design-based investigation (2010 through 2015) into collaborative philosophical inquiry (CPI) in an inner-city primary school that serves a multicultural community in Brisbane Australia. CPI in the classroom is a deliberative, dialogic process that aims to develop complex thinking and prepares students to become critical, creative and caring thinkers and reasonable, active citizens throughout their lives. The first author (Fynes-Clinton) established CPI as the pedagogical method that informed curriculum planning, development and implementation at the school. The CPI approach at the school was based on the original work of Lipman (1980) and later adaptations incorporated by practitioners in the context of Australian schools (e.g., Chesters et al., 2013). Over the past six years, the school had undergone a significant cultural shift in thinking and behaviour. There has been an identifiable lift in students' engagement in learning and academic outcomes as assessed through the national literacy and numeracy program of assessment (NAPLAN). Moreover a recent review of the school in 2015 by an external evaluator identified CPI as playing a key role in creating a more peaceful, caring and respectful community.

This paper examines a particular feature of CPI, namely genuine doubt, which was identified as crucial to episodes of high quality student talk (Hilderbrand, 1996). The notion of *genuine doubt*, was proposed by the pragmatist Charles Sanders Peirce (1877) as key to collaborative inquiry. Peirce maintained that inquiry forms the space between genuine doubt and a fixed or settled belief. Peirce contrasted genuine doubt with 'paper doubt,'

a term he coined to reject Descartes' position on doubt as grounded in the theoretical rather than in practice. Peirce perceived genuine doubt to occur when an action or 'real' experience brings about a feeling of disequilibrium, resulting in one's need to revise an existing belief, thus initiating an inquiry process. Later he reviewed his original ideas about genuine doubt, proposing that philosophical inquiry may commence with 'cultivated doubt' that leads onto genuine doubt. (Hilderbrand, 1996; Pardales & Girod, 2006; Peirce, 1877).

This paper draws upon a corpus of data from specific groups of students which included transcripts of shared dialogue during CPI, student interview transcripts, student artefacts and teacher reflections. Data collection was implemented over two key phases. Phase one commenced with the school's introduction of CPI in 2012 in two multi-age classes: a Year 2/3 and a Year 4/5 class. The key focus of this phase was on the students' development of intellectual habits of thinking and learning that included for example, analogic reasoning, distinction making, justification of viewpoints, criteria building and testing reasoning with counterexamples. The second phase of the study was implemented in mixed year level classes during the second semesters of 2013 (students from years 2 to 7) and 2014 (students from years 4 and 5). The student participants were selected for these classes due to their interest or skill in the learning area of philosophy. Students were introduced to the allegory of Plato's Cave and specific philosophers' theories of knowledge, wisdom, reality, existence and identity. The key focus of the research was students' reconstruction of thinking habits in response to authentic inquiries based on students' questions and connections they made to key philosophical theories (Dewey, 1957). This enabled students to reach beyond the intent of the school curriculum and provided opportunities for the cultivation of genuine doubt amongst the young inquirers. The following is an example of the kind of dialogue associated with an episode of genuine doubt. During this inquiry, the students were considering the possibility that people often fear the unknown and this fear may prevent one from gaining wisdom about the world.

> **Year 7 student 1:** As I was listening to everyone it made me think a bit more – and think about having wisdom. I don't think you can be afraid if you have no wisdom because what leads to being afraid is you think about something and that leads to fear – like you are scared of something that you think of – and I think – I – wisdom is the key that can open any door – like if you have wisdom you can open the door to fear – you can open the door to like, questioning the things you think in your mind and you become a lot more wise.
>
> **Teacher:** What do you think about that idea? (Student) doesn't think you would be fearful if you didn't have wisdom. It's not possible to be fearful without wisdom?
>
> **Year 4 student:** (Student) said that wisdom opens many doors. Does it start fear or stop fear? (Further questioning and comments by students and teacher)
>
> **Year 7 student 2:** I want to extend on Josh's idea. I think wisdom is like the key to unlock, like, fear. You have fear of the unknown – fear of that which you do not understand and knowledge takes away the cloak of misunderstanding...

The initial analysis indicates that genuine doubt creates opportunities for students to build upon each other's contributions and creates a sense of a community of inquiry where students' concerns and values can be shared and interrogated within the community. Students become invested in the establishment of a democratic community of learners within their classroom (Dewey, 1916). This forms the basis of a more democratic and caring school community. Genuine doubt arising from authentic inquiry within the classroom enables students to consider ideas from a range of perspectives and thus gain a deeper understanding of the value and significance of democracy.

Engaging with issues through controversy mapping in a school science context

Anne Solli, Thomas Hillman and Åsa Mäkitalo, University of Gothenburg

Public debates of science and technoscientific innovations rely heavily on digitized information; they are available through digital media and are generative of new uncertainties in the everyday lives of citizens. In concrete terms they concern issues such as global warming, GMO, hydraulic fracturing etc. The field of science education have responded to the concern for scientific citizenship by introducing so called socioscientific issues (SSI) in school that invite students' engagement with scientific, societal, ethical and cultural perspectives on such issues (Zeidler & Nichols, 2009). For teachers who wish to engage their students in ongoing debates, it is a challenge to invite the complexity of such issues as they rely on digitized information. As students turn to the Internet, such debates take place in a mixed stream of website-genres, modalities and difference of opinion (Lemke, 2006). Their

challenge is to navigate their way through a vast amount of disparate voices, claims, arguments, insights and experiences. In this situation, ways of mapping controversies through the extraction and analysis of digital data (Venturini & Latour, 2010) may provide a means to display such information in a more condensed and readable form – a map to be used for further exploration (Venturini, 2010).

Controversy mapping has been claimed to provide alternative routes for students to engage with technoscientific issues of concern. While SSI projects typically have emphasized the exploration and appropriation of different scientific forms of reasoning and ethical considerations to support individual decision making (Sadler, 2011; Nielsen, 2013), controversy mapping sees new forms of technical mediation as the key to improved science literacy and public engagement. Whatever might be the case, we know that there is a rich variety of digital tools and applications available and that there is a need to focus on their actual use before drawing any conclusions about their implications for student learning. The precise manners in which tasks are initiated, what resources are available and how students' work will be assessed, have clear implications for their ways of engaging with such issues (Furberg & Ludvigsen, 2008; Åberg, Mäkitalo, & Säljö, 2010). This calls for empirical studies that scrutinize *how* controversy mapping with digital tools constrain and/or support students' learning about current matters of concern for citizens, which is the aim of our study.

Our conceptualization of learning as appropriation is analyzed through *mediated interaction,* which focuses the ways that semiotic means are entangled in student's sense making as material sign vehicles (Wertsch, 2007). Appropriation implies that students familiarize themselves with the mediating means that are salient in their environment and learn to use them through interaction with others and in response to local concerns. In this particular study, we explore the heterogeneity of genres and social languages (Bakhtin, 1981) that become salient in students' activities as they navigate complexity with the map as a point of departure.

Empirically we have followed two classes (grade 11 and 12) in an upper secondary school were they worked with controversy mapping as part of a project concerned with science-in-society lasting 3 weeks. The students begin by selecting a controversy, they are introduced to scraping data from the Internet using Navicrawler, and then learn to *re*-present that data in visual form using Gephi (creating a digital map of a network of actors involved in the controversy). Our data for this study consist of video recordings of two groups of students in an activity where they are to explain the controversies they are exploring to fellow students, using the maps they have created. We analyze how they negotiate meaning, relevance and reliability and handle the many voices and different accounts they encountered through their map-making.

Our preliminary analysis show how the digital maps support the discussion by visually stabilizing the stakeholders and positions, making them publicly and jointly available for discussion. It also supports and sustains a dialogic space in which students can orient to multiple perspectives. The students engage in questioning claims of their fellow students and of stakeholders in their controversy. They also engage in justifying positions, explaining together, evaluating sources, and used the maps for understanding conflicting versions of the issue. The students also need to account for the processes of making their maps; how they were constructed and what they *re*-present. This implies that these students both negotiate and rely on these resources as vehicles for scrutinizing, reasoning and arguing. The students were challenged in appropriating the tools, but seemed to establish a space of reflection. This space provided possibilities for the students to question their own assumptions and submit themselves to the tension of conflicting viewpoints (Wegerif, 2013). We will conclude our paper by drawing on what the discussion of these students imply, in terms of fostering a young citizen agency.

Computer-supported deliberation about hot historical topics in a multi-ethnic context

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History began to be taught as a school discipline in Western countries from the middle of the nineteenth century only. At the time of the Spring of Nations, the newly born Nation-State needed its citizens to share common values and beliefs. The most natural candidate for commonality was the official narrative that told the story of a nation. For a long time, textbooks provided indisputable narratives from which students were expected to extract facts or interpretations. The History of the 20th century is a tremendous slap in the face of values in Western Nation-States. Except for citizens who identify with radical right wing parties, there is a general consensus on some degree of opening up to other cultures. Waves of immigration have also changed the cultural background of many schools in Western countries to include students from different countries with different cultures and values. These changes are particularly challenging for History teaching, especially in countries where conflicts are still alive (or even memories of them). In this context, educators have adopted different pedagogical approaches. Goldberg (2013) identified three pedagogical approaches that are implemented nowadays in history classrooms. The *authoritative-conventional approach* (by far the most frequent approach) presents to the student a unique narrative

that reflects the point of view of the nation-state. This approach is often presented as a way to apply a 'melting pot' policy for increasing shared values and beliefs among future citizens of the same country. The *critical-disciplinary approach* consists in the appropriation of the concepts, practices and reasoning skills characterizing history as an academic domain. Contextual thinking (which denies an attitude toward the past dominated by present-day attitudes and experiences), evaluation of sources, and syntheses based on multiple (and conflicting) texts, are central according to this approach. Historical sources are referred to as testimonies to be treated with circumspection. The third approach is the *empathetic-narrative approach*. It consists of organising encounters between students from groups with conflicting narratives, and encouraging them to express and listen to alternative interpretations of events. This approach is particularly suitable in countries where conflicts are still vivid, but not only in such countries. It is characterized by the absence of judgmental expressions, and of defensive reactions.

Goldberg (2013) compared the three approaches in Israel – a country involved in a conflict with respect to national identity, commitments to in-group narratives, interest in out-group perspectives and conceptions of the conflict, for a unit on modern history focusing on the 1948 war of independence between Jews and Arabs. Jews and Arabs participated in small group discussions in the study. He showed the superiority of the critical disciplinary approach and of the empathetic-narrative approach, and the inferiority of the authoritative- traditional approach. These results are even more surprising in the light of the fact that students perform poorly when invited to argue about dormant historical issues (Pontecorvo & Girardet, 1993), and that students often treated sources as information and only used the information that supported their claim (Lee & Ashby, 2000). The reasons for the productivity of progressive approaches for emotionally-charged, ethnicity-related historical controversy historical issues partly originates from meticulous argumentative design (evaluation of multiple texts, individual argumentative essay, dialectical argumentation in small groups and final essay) (Goldberg, Schwarz & Porat, 2009).

The dimension generally scrutinized in the context of group learning generally concerns the conceptual or the ideational. However, other dimensions the epistemological and the interpersonal dimensions are crucial, especially in long-term learning experiences (Schwarz & Baker, 2016). Our research shows that the approach adopted for history teaching impinges on the nature of discussions in class (teacher-led, or in small groups) is influential both to the construction of group identity and to improvement or deterioration of intergroup relations. Differences in effects of the approaches we study are salient not only in outcomes but in the quality of discussions between groups (Schwarz & Shachar, in press). We have shown that the role of emotions according to the critical-disciplinary and the empathetic-narrative approaches can often be beneficial in small-group discussions. Analysis of some discussions amongst students representing conflicting groups, who read and evaluated conflicting sources, revealed that emotions were intense but did not impair the deployment of rich argumentative moves (Schwarz & Goldberg, 2013). On the contrary, in certain cases, emotions fuels small group argumentation and does not impair clear thinking in a case where the conflict had already been settled but had left emotional scars.

Research done so far on small group emotionally-loaded discussions in History in a multicultural context has been conducted in short-term interventions. We have currently engaged in research on discussions between Arabs and Jews about controversial issues in the Modern History of the State of Israel. The on-line modality is propitious for such a context. Students typically interact in dyads in consecutive activities (evaluation of sources, preparation for debate in same ethnicity group, critical discussion, collaborative writing). Through the use of scripts that encourage a disciplinary, empathetic or authoritative approach, we manipulate the emotions of the participants. Also, in the course of the consecutive activities, we introduce historical issues for which collective memory has different levels of vividness. This setting is intended to check changes of viewpoints from epistemological deontic, conceptual and interpersonal perspectives in the long-term. If our first impressions will be confirmed, the prolonged learning experiences based on a combination of critical- disciplinary and empathetic-narrative approaches may lead to argumentative forms of deliberation, in which epistemological and intersubjective dimensions will develop positively. Such envisioned outcomes might lead the students involved in these learning experiences to be ready for the constitution of a deliberative democracy.

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The Learning Sciences @ Scale:
Current Developments in Open Online Learning

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Abstract: The explosive growth of MOOCs has generated immense interest in online learning in massive courses. However, much of this frenetic activity has emphasized technology and scalability (Reich, 2015), resulting in rudimentary learning experiences (i.e., brief streaming videos followed by quizzes or online discussion forums). This symposium will showcase and discuss four diverse efforts to advance open learning at scale that are directly informed by contemporary theories of learning and educational research methods. This includes research on inquiry-based community learning, computer-mediated discourse analysis, participatory approaches to learning and assessment, and evidence-rich digital-credentials. In each of the four cases, the desire to extend that program of research to learning at scale resulted in significant advances in the more general program of research. In this way the symposium explores efforts to foster learning at scale might advance our theories of learning and our principles and methods for learning design more generally.

Keywords: learning design, online learning, informal learning, learning communities

Introduction

The explosive growth of MOOCs, which have not tended to include complex instructional designs (Reich, 2015), has sparked the interest of researchers in the learning sciences. These innovators see the opportunity for investigating new modes of learning, including new forms of socially mediated materials and activities and new pedagogical affordances for learning at scale (e.g., through learning analytics and educational data mining). This symposium will present a set of papers that describe research of such new opportunities. We recognize the unique aspects of MOOCs where participants arrive with altruistic learning goals, situated within diverse contexts – often from around the world, in all time zones and a wide range of settings – with legitimate interest in engaging with peers and participating in the learning designs. Many of the elements of MOOCS are quite challenging, such as the asynchronous, distributed aspects of participation, the high variation amongst learners in terms of their background and available time, and the lowest common denominator of end user technologies. However, some features have captured our attention, and offered new opportunities for research in our design of pedagogical scripts, collaborative learning environments, and interactive materials. In some cases, this work could potentially return new theoretical insights and methodological capabilities for the wider learning sciences community. We will discuss the implications of our work, the likely trajectories of MOOCS in the coming years, and way that this nascent community within ISLS can help advance

Growing pains and a push for greater interactivity

The earliest MOOCS, known as "cMOOCs" were based on a contemporary view of learning called connectivism (Siemens, 2005) and aimed to support robust peer interaction and networked knowledge construction. However, it has been the subsequent form, known as "xMOOCs" that formed the heart of the rapid expansion of course offerings. Variously attributed to "eXtended" or "eXtension," the online courses at edX, Udacity, Coursera, and others, these courses generally feature streaming videos, online readings, problem sets and quizzes, and peer discussion forums. Once developed, most courses could be offered to new cohorts of learners for very modest costs, and sometimes simply left online for any and all to complete at their own pace. This general model has expanded to many other platforms and sectors and has become quite pervasive, even in smaller more exclusive contexts such as corporate training and for learning towards specialized certifications.

Amidst the "hype and hyperbole" over MOOCs, several certainties emerged by 2012, which the New York Times dubbed "the Year of the MOOC" (Pappano, 2012). In addition to the aforementioned massive expansion of opportunities, other certainties were that MOOCs were generating extensive innovation in online

learning more broadly, and that MOOCs were causing many observers to reconsider the design and (particularly) the cost of existing models higher education. Another certainty that emerged around this time is that most MOOCs featured much less interaction than is typical of face-to-face courses. Some observers had already commented on the difficulty of connecting with other learners in the cMOOCs (Mackness, Mak, & Williams, 2010) It turned out that supporting social interaction in the cMOOCs was proving *much* harder. An effort to include more interaction and group projects in a Coursera course on online learning was widely cited for going "laughably awry." (Oremus, 2013). One study found that engagement in Coursera discussion forums declined significantly over time among completers, and that instructor involvement actually worsened participation; A consensus emerged that most MOOC discussion forums suffered from sharp declines in interaction as courses got underway, and that this was mostly likely due to "information overload" as discussion threads become unnavigable and veered off topic (Brinton, 2013). This relative lack of social interaction was one of the most oft-cited concerns in the "backlash" against MOOCs one year later (Kolowich, 2013).

MOOC proponents generally responded that the social experience in typical MOOCs was actually quite similar to what many students experience in the large lecture courses that are typical for introductory courses in many college and universities. Indeed, the peer discussion forums available for many MOOCs were similar in ways to the informal study sessions that many students organized themselves into for conventional lecture courses. Furthermore, some discussion forums were moderated by knowledgeable volunteers and even sometimes by paid teaching assistants. Regardless of the reality in 2013, significant effort was already underway among MOOC innovators and researchers to study social learning and more systematically support more and more productive peer interaction. Some of this research was more naturalistic research continuing in the tradition of the cMOOCs. A team at Stanford was developing a MOOC platform (now called NovoEd) which is explicitly based on social learning theory (Ronaghi, Saberi, & Trumbore, 2015). A major program of research at the Open University resulted in the FutureLearn which supports "discussion-in-context" and "community-supported learning" in dozens of free open online courses (Parr, 2013). A particularly promising related strand emerged around scaled up efforts to support peer assessment of extended student work (Kulkarni, Socher, Bernstein, & Klemmer, 2014).

Structure of the session

Other promising efforts to study and support social learning at such a scale have drawn on the insights from the Learning Sciences and Computer Supported Collaborative Learning communities. This symposium features four such efforts from learning science science research groups, organized as a set of four synthesized paper presentations with a panel format for the discussion. Each presenter will (a) address the prior theories and research that is informing their work, (b) show how those theories are instantiated in new learning features, (c) demonstrate the forms of engagement supported by those features, (d) summarize the evidence showing the impact of these features for students, (e) articulate design principles for supporting learning at scale, and (f) highlight current challenges and near-term goals for continued refinement and research. Following the presentations, each of the four presenters will pose one question of another presenter, followed by a wider panel commentary on that question. At the end of each panel discussion, there will an opportunity for audience questioning, moderated by the chair.

Supporting reflection and collaboration in a MOOC for in-service teachers

Hedieh Najafi, James D. Slotta, Stian Håklev, Renato Carvalho, and Rosemary Evans, University of Toronto

"Teaching with technology and inquiry" (INQ101x) was a six-week MOOC designed for in-service teachers interested in learning how to integrate technology and inquiry into their own practice. The course was co-led by a professor and a school principal, and showcased the viewpoints of school administrators and classroom teachers.

INQ101x applied Knowledge Community and Inquiry model (KCI; e.g., Slotta, & Najafi, 2012) to a large-scale context with more than 8000 registered participants. KCI informed our design of a "script" where participants created and applied a collection of annotated resources for teaching with technology and inquiry, and a subset of participants opted to collaboratively design a lesson plan, working in small groups and receiving feedback from the wider community. Two live events in the last week of the course allowed learners to discuss their questions with the course instructors and with master teachers who had contributed to INQ101x. To foster in-depth discussions among learners, we used learners' professional background to create 10 Special Interest Groups (SIG). Learners chose their SIGs after completing a pre-course survey, a mandatory step to join design groups and SIG specific discussions. Of all registrants, 2008 learners completed the survey, 357 learners joined design groups, and 120 active design groups were formed. More than one thousand annotated resources were submitted to the resource collection.

Given the high number of learners enrolled in INQ101x, providing personal feedback to learners was impractical. Thus, reflection prompts and shared reflective notes were used as a means to promoting deep reflection about course content. Two types of reflection notes were integrated in INQ101x: individual private reflection notes and public reflection notes submitted to course discussion forums and discussed with peers. An example of a public reflection note was: *"Lets talk about the pragmatics of student-contributed content and collective inquiry. When we assign students to create, curate, re-mix and apply ideas and observations, how can we make sure that every student gains the benefits: creating and contributing resources, engaging in productive exchanges with peers, and drawing upon the collective resources?"*

Creating opportunities to foster reflection is integral to teacher education and professional development programs, to help teachers apply new concepts and approaches to their practice, and build new forms of practitioner knowledge (Madeira & Slotta, 2012; Pavlovich, 2007; Spalding, & Wilson, 2002). Reflective notes, shared or private, prompted or non-prompted, are used to encourage teacher reflection (Chitpin, 2006). Lee (2010) argues that sharing reflections with peers can help teachers to improve the depth of their reflections. Blomberg et al. (2014) identify three levels of teacher reflection, with increasing levels of sophistication: description, evaluation, and integration.

We examine the impact of participation in such reflections on INQ101x learners' knowledge of teaching with technology and inquiry. We address the following research questions: (1) How do personal reflection notes evolve over the six weeks of the course? and (2) How does peer feedback received through public reflection notes contribute to progress in teacher understandings over the six weeks of the course? We adapted an existing rubric for assessing the quality of personal and public reflection notes in INQ101x (Hatton, & Smith, 1995; Moon, 2013) as: non-reflective, descriptive reflection, dialogic reflection, and critical reflection. Reflection notes of science and math teachers were included in the data set. We apply our findings to create a set of principles that can guide the design of effective reflection and discussion prompts for large online courses.

Envisioning support of social learning in MOOCs

Carolyn P. Rosé, Carnegie Mellon University

Data from Massive Open Online Courses (MOOCs) offer evidence of the association between types of conversational interactions and retention (Wen et al., 2014a; Wen et al., 2014b; Wen et al., 2015), team project quality (Yang et al., 2015), and learning (Wang et al., 2015) in the environment. These insights inform design of interventions to support improved outcomes (Howley et al., 2015; Ferschke et al., 2015a; Ferschke et al., 2015b). This work represents a series of investigations related to the broad vision of designing and building out affordances for collaborative learning in MOOCs through DANCE[1].

If we can leverage the rich potential source of support in the plentiful student population in MOOCs, we may be able to substantially reduce attrition and meet instructional goals better at the same time. The area of automatic collaborative process analysis has focused on discussion processes associated with knowledge integration. Frameworks for analysis of group knowledge building are plentiful and include examples such as Transactivity (Berkowitz & Gibbs, 1983; Teasley, 1997; Weinberger & Fischer 2006), Inter-subjective Meaning Making (Suthers, 2006), and Productive Agency (Schwartz, 1998). These discussion processes are theorized to occur when students adopt an orientation towards one another in which they are most likely to experience cognitive conflict and learning (de Lisi & Golbeck, 1999). Automated analysis technology (Rosé et al., 2008) enables triggering support for these types of interactions in an automated way (Adamson et al., 2014).

MOOCs are not unique in their pattern of exponential attrition over time. Instead, the same pattern is evident in all forms of online communities. Social support exchanged through discussion forums is known to be associated with increases in commitment and corresponding reductions in attrition in online communities (Wang, Kraut, & Levine, 2012). Findings from our own MOOC deployment in Fall 2014 provides evidence that the experience of a synchronous collaborative chat in the midst of MOOC participation reduces attrition at the time point of the experience by more than a factor of two (Ferschke et al., 2015b).

Our early intervention was designed for short, periodic collaborative exchanges. More recently we have been working towards more persistent social interaction throughout a course in the form of team based projects. Our analysis of data from two team based MOOCs suggests that the success of teams in state-of-the-art team based MOOCs is low (Wen et al., 2015; Yang et al., 2015). While the behavior of team leaders, and to a lesser extent that of other team members, predict team outcomes, the evidence points to the conclusion that the problem starts even before the teams begin to function in that capacity. In particular, the team formation process itself must be improved in order to produce teams that are positioned for success at the start. We propose a deliberation-based team formation procedure to improve the selection and initiation process leveraging the same discussion processes associated with enhanced learning. What that means is that a pretask is assigned to students to do individually

and then post to a public discussion forum for feedback from other students in the class. Students are required to select a small number of students to provide feedback to in this context. An automated process analysis tool is then used to make an assessment about the number of transactive contributions exchanged between each pair of students in this context. A constraint satisfaction algorithm is then used to assign students to teams in such a way that the average pairwise observed exchange of transactivity from the discussion forum activity between students assigned to the same team is maximized across the student population. Results from pilot investigation in MTurk suggest strong effects both of deliberation pretask with feedback from fellow-students and team selection based on automatically detected transactivity in during this pretask discussion.

Scaling up participatory approaches to learning and assessment in open courses

Daniel T. Hickey, Suraj Uttamchandani, and Joshua Quick, Indiana University

This paper argues for a gradual iterative response to pressures to scale up learning, so that technology can respond to rather than constrain theoretical advance. This research embraces situated and participatory perspectives on learning (Greeno et al., 1998) and assessment (e.g., Moss, et al., 2008, Hickey, 2015). A prior program of design-based research resulted in a core set of design principles, local theories, and specific practices for fostering broad learning outcomes and measuring those outcomes in technology-supported learning environments. By aligning informal, semi-formal, and formal assessment, these efforts have delivered very high levels of socio-technological engagement with disciplinary knowledge (as in Engle & Conant, 2002), while leaving behind dramatically enhanced understanding and significantly enhanced achievement (Hickey & Zuiker, 2012)

The data for the most recent cycle of research comes from an online graduate course on Educational Assessment. A conventional version of the course in both Sakai and Google Sites was refined over several years in order to overcome the constraints of these platforms on participatory learning (Hickey & Rehak, 2013). With the support of a grant from Google, the resulting design principles were further refined in three annual "big open online courses" ("BOOCs") using in an extensively customized version of Google Coursebuilder. The first course started with hundreds of learners, including a subset of students taking the course for credit. Each cycle has further automated key features, including personally contextualized registration and participation, assignment to networking groups, personalized "wikifolio" open assignments, anchored peer commenting, contextualized analytics and feedback, peer endorsement and promotion, and open digital badges for completion, leadership, and advanced work.

This research has led to further refinement of the course design principles, which are now as follows: (1) Use public contexts to give meaning to knowledge tools; (2) publically recognize and reward productive forms of disciplinary engagement; (3) assess student generated artifacts through local reflections, (4) help learners self-assess their understanding privately, and (5) measure aggregated achievement discreetly.

Analyses from the most recently completed Assessment BOOC revealed levels of persistence comparable to others MOOCs: 11% of the 179 registrants and 29% of those who completed the first assignment completed the course. But this analysis revealed dramatically higher levels of individual and social engagement than most MOOCs support. Weekly wikifolios averaged 2,820 words for credential students and 1,377 words for open completers; credential students averaged 4.2 comments per week and 337 words per comment while open students averaged 3.7 comments per week and 302 words per comment. Coding of the comments revealed that around 90% of the comments were disciplinary (because they referenced the topic of the assignment), while 25% were contextualized (because they referenced a specific practice context). We also obtained satisfactory levels of achievement on a timed exam consisting of challenging multiple-choice items (averaging 80% for credential students around 78% for open students).

This research is significant because it has resulted in streamlined features to support participatory learning at scale. With modest additional work, these features can be shared broadly as open source modules that can be easily integrated into other platforms via Learning Technologies Interoperability (LTI) standards.

Orchestration graphs: How to scale up rich pedagogical scenarios

Pierre Dillenbourg, EPFL, Switzerland

The goal of orchestration graphs is to describe how rich learning activities, often designed for small classes, can be scaled up to thousands of participants, as in MOOCs (Dillenbourg, 2015). A sequence of learning activities is modeled as a graph with specific properties. The vertices or nodes of the graph are the learning activities. Learners perform some of these activities individually, some in teams and other ones with the whole class. The graph has a geometric nature, time being represented horizontally and the social organization (individual, teams, class)

vertically. These activities can be inspired by heterogeneous learning theories: a graph models the integration of heterogeneous activities into a coherent pedagogical scenario.

The edges of the graph serve to connect activities, representing the two-fold relationship between activities: how they relate to each other from a pedagogical and from an operational viewpoint. From the operational viewpoint, edges are associated with operators that transform the data structures produced during a learning activity into the data structures needed to run the next activity. From the pedagogical viewpoint, an edge describes why an activity is necessary for the next activity: it can, for instance, be a cognitive pre-requisite, a motivational trick, an advanced organizer or an organizational constraint.

The extent to which one activity is necessary for the next one is encompassed in the weight of an edge. The transition between two activities is stored as a matrix: the cell (m,n) of a transition matrix stores the probability that a learner in cognitive state m will evolve to state n in the next activity. This transition matrix can be summarized in the form of a parameter that constitutes the edge weight: an edge between two activities has a heavy weight if the learner performance in an activity is very predictive of his success of the connected activity. The graph also constitutes a probabilistic network that allows predicting the future state of a learner. An orchestration graph describes how the scenario can be modified, stretched, cut, extended.

This presentation will begin with a review of the orchestration graph approach, illustrating the application of such an approach in several activity designs. Following, the sequence of activities from one recent MOOC will be presented in terms of orchestration graph, revealing transitions between "orchestrational layers" and suggesting new opportunities for learning analytics.

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Real-Time Visualization of Student Activities to Support Classroom Orchestration

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Abstract: Data logged within technology-based learning environments have the potential to support instructors' orchestration of learner activities. Whereas many learning environments now feature student and teacher dashboards, which promote reflection on activities after the fact, the affordances of displaying these data in real time is only beginning to be explored. To be useful, however, these data must be made accessible and actionable. This interactive demonstration will showcase designs for technologies that visualize student activities in real-time during technology-enhanced activities, with the aim of supporting instructors' orchestration. Together, they projects from various contexts with similar goals, it highlights common challenges, issues, and strategies with regard to the design and implementation of these tools.

Keywords: classroom orchestration, design, information visualization, real-time data, teachers, technology

Introduction

The trend toward technology-enhanced, open-ended inquiry-based curricula (Scardamalia & Bereiter, 2006; Engle & Conant, 2002; Slotta & Linn, 2009) is placing a higher orchestrational load on teachers (Dillenbourg 2012; Tissenbaum & Slotta, 2015a). As students engage in more self-paced, choice-driven, and collaborative learning environments, the task of guiding student progress grows more complex. While telemetry data—that is, measurements captured and displayed for the purposes of monitoring—are proving advantageous for research into student learning (Baker & Siemens, 2014), solutions for harnessing this data as a tool for teachers have only begun to be explored. In spaces where learners' knowledge evolves at different paces and across multiple trajectories, teachers are faced with such decisions as when, who, and how to help (Tissenbaum & Slotta, 2015b); how to pace whole class and individual progress (Nussbaum, Alvarez, McFarlane et al., 2009; Roschelle, Rafanan, Estrella et al., 2010); how to distribute materials (Simon et al., 2004); and how to organize and manage the social structures among students across online and face-to-face settings (Dimitriadis, 2012). This *orchestration* of classroom activities (Dillenbourg, Jarvella, Fischer, 2009) has been highlighted as a major research design challenge within the learning sciences community (STELLAR, 2011).

In response, there has been increased interest in the affordances of technology-enhanced environments to support learning activities in real-time through automated scoring and guidance, real-time mining of telemetry data, and adaptive feedback (VanLehn, 2011; Berland, Davis & Smith, 2015; Leacock & Chodorow, 2003). While these technological solutions can reduce teachers' orchestrational load, it is important to ensure that teachers continue to have active roles as conductors of classroom activities rather than as "guides-by-the-side" (Koller et al, 2011; Roschelle & Pea, 2002). To this end, we investigate technologies that can provide teachers with more control over class progression and actionable real-time insight into the state of knowledge at the individual, group, and whole class levels. Generally termed orchestrable or orchestable technologies (Tchounikine, 2013), these

tools provide teachers with specific insight into the state of the class and provide and an added layer of flexibility in how classroom activities unfold. An important feature of such technologies is that they do not require the teacher to take action, nor does the system itself take action, rather they give the teacher better information to help him or her make decisions (Tissenbaum, 2014). These technologies take on many forms, including tablet-based dashboards, ambient displays, and other similar aggregated visualizations.

While these technologies are growing in popularity, the various ways they have been implemented and a thoughtful comparison of their relative successes (and where they have fallen short) has not been presented in a unified way. To address this need within the learning sciences community, this symposium brings together five projects that are investigating the role that orchestrational technologies can play in giving real-time classroom support. During the symposium, participants will discuss the curricular context in which it is situated, the orchestrational needs they aimed to address, and the successes *and shortcomings* of their implementation.

Objectives

Together, these contributions aim to start conversations about issues involved in designing and implementing these systems: What data should be captured, and who should make this decision (Matuk, Cocco & Linn; Tissenbaum, Berland & Lyons)? What activities should these data support (Schwendimann; Tissenbaum & Slotta)? How should these technologies be integrated into teachers' practices (Matuk, Cocco & Linn; Vitale, Gerard & Linn)? How should these data be visualized (all)? These works also investigate affordances of technology and information visualization for supporting sociality, collaboration, decision-making, and inference. This symposium will create opportunities to examine commonalities and divergences in strategies, theoretical frameworks, and pedagogical goals of efforts to harness data in support of in-the-moment teaching. It will fuel discussions among the Learning Sciences community of concrete solutions to the problem and advantage of data in education.

Contexts, settings, and foci

The contributions represent different pedagogical contexts, including game-based learning (Plass), workplace training (Schwendimann & Boroujeni), and science inquiry (Matuk, Cocco & Linn; Tissenbaum & Slotta; Vitale, Linn & Gerard). They also cross physical settings, from formal (e.g., K-12 classrooms) to informal spaces (e.g., workplaces and museums). The foci of contributions range from understanding how such tools can support the seamless transition of learners' activities between learning settings; to justifying design decisions and exploring associated student learning gains; to investigating how technology can alert teachers and/or mentors of critical moments for intervention. All contributions place an emphasis on teacher-centered design, valuing teachers' existing practices, and investigating ways technology can enhance those practices.

Session format

To promote active and productive discussion, the format of this symposium will be an interactive demonstration. Following brief teaser presentations on each project, the audience will be invited to explore stations at which presenters will have set up demonstrations of their technologies. They will have a chance to explore and critique these designs in terms of their value for orchestrating learning activities. During the final portion of the session, we will return to a whole group format. Our discussant will offer insights, and the audience will be invited to ask questions, and to contribute reflections on their own and the presenters' work.

Designing a real-time intelligent support for museum interpreters

Mike Tissenbaum, Matthew Berland, and Leilah Lyons

With the increasing inclusion of technology rich interactive and immersive exhibits in museums there is a growing challenge to supporting docents in knowing when participants are struggling at an exhibit and if they are close to "giving up." This is especially true in exhibits where multiple participants can engage at the same time and can enter or exit the exhibit within the flow of activities (rather than a simulation or activity having clear start and end points).

In response to the challenge of supporting museum docents within open-ended museum exhibits, we have developed a tablet application for an interactive tabletop exhibit (called *Oztoc*) at the New York Hall of Science (Lyons et al., 2015). The tablet application (Figure 1) collects the real-time logs of participants' actions, and based on their emergent patterns, alerts the docent when a participant is engaged in "unproductive perseverance" (continuing to repeat the same pattern over and over) or is close to a "frustration point" (i.e., about to give up). In order to recognize which patterns were most indicative of participants engaging in either condition,

we used a combination of grounded theory stemming from video observations of participants engaged around the table and sequential data mining (an educational data mining technique that highlights underlying patterns in complex data sets).

As part of this symposium, we will show how patterns for intervention are identified and selected, museums docents' feedback on the use of the tablet, and an analysis of data from a live museum context. We will also make the tablet application and source available for those interested.

Figure 1. Oztoc real-time docent tablet application screen.

A teacher-centered approach to designing a real-time display of classroom activity

Camillia Matuk, Felipe Cocco, and Marcia Linn

Online learning platforms, such as the Web-based Inquiry Science Environment (WISE, wise.berkeley.edu), are evolving to capture nuanced pictures of the processes, in addition to the outcomes, of student learning. As such, they make it possible for teachers to quickly ascertain patterns in students' thinking, and to devise more timely and targeted guidance. However, many questions remain about how to best make this information accessible and useful to teachers, as well as about how to integrate the resulting tool into teachers' existing practices.

We describe the design of a real-time summary report that displays students' progress based on data logged by WISE (Figure 2). Information boxes display averages of such information as the time spent on a step in a unit, the number of visits to each step, and the number of revisions per step. These boxes include a snapshot of ranked data (e.g., a list of the top three steps on which the most time was spent), which on clicking, lead to explorable visualizations of whole class data. With this information, teachers can streamline instruction, promote student reflection and motivation, identify students in need of help, identify areas in the unit for improvement, and manage students' progress (Matuk et al., 2016).

Audience members will be invited to explore a live summary report and associated data displays. We will discuss how, through classroom observations, teacher interviews, and participatory design workshops, we come to determine and refine visualizations appropriate for their anticipated functions. Building on prior work, which reveals which logged data teachers prioritize for which decisions (Matuk et al., 2015, 2016), we discuss our explorations into the display of new information, with the aim of supporting evidence-based instruction ranging from planning logistics (e.g., how to pace progress given the steps students may have skipped); to selecting guidance strategies (e.g., what feedback is most effective based on students' improvement through revision); allowing teachers to draw on archived data from their own and others' past curriculum implementations to inform current implementations; and making correlations among available data to answer their own questions about student learning.
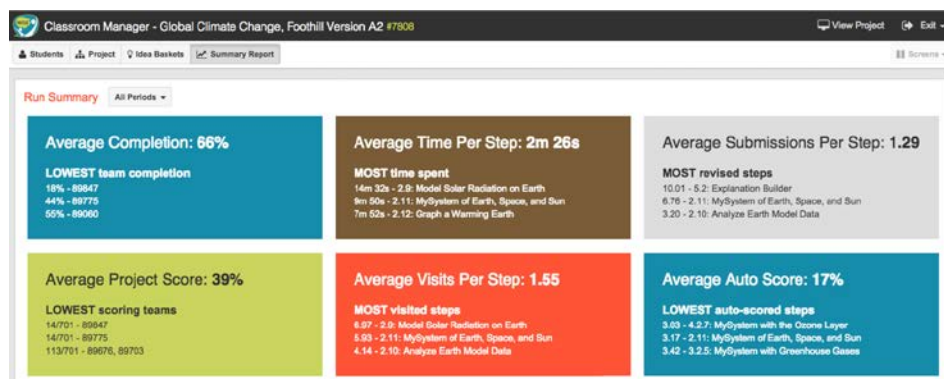
Figure 2. WISE's classroom summary report.

Real-time visualization of student activities during learning with simulations and games in the Digital Reference, Experiment, and Assessment Manager (DREAM)

Jan L. Plass, Nik Hajny, and Al Olsen

This demonstration will show how we present real-time information of student activities during learning with simulations and games to instructors. In order for real-time information to be useful for classroom orchestration, it needs to be current yet not updated too frequently; aggregated enough to be easily comprehended, yet detailed enough to be informative; and actionable without being too prescriptive.

Based on our previous work investigating how teachers use games as tools for formative assessment in the classroom (Fishman, Snider, Riconscente, Tsai, & Plass, 2015), we are designing a visual dashboard for simulations and games in our Digital Reference, Experiment, and Assessment Manager (DREAM) platform that makes key information available to instructors in ways that meet the above requirements. Based on this research, this dashboard (1) links the game's incentive structure (points, scores, stars) to learning outcomes, (2) provides learning progress for either individual students or groups of students, (3) incorporates outcomes from other, related activities students performed concurrently or in the past, and (4) allows teacher to configure the display of the information to meet their needs (Figure 3). In particular, teachers are able to switch among views with different levels of granularities of the data. This could be as coarse as visualizations of the overall progress of the class on specific learning objectives or standards, or more detailed showing class progress on specific sub-standards. Other visualizations show the overall class progress on performing a specific task or activity, progress of an individual on performing this activity and their comparison to the class average, or specific information of individual in-game events and student responses. Figure 3 shows the top level page from which this information will be accessible.
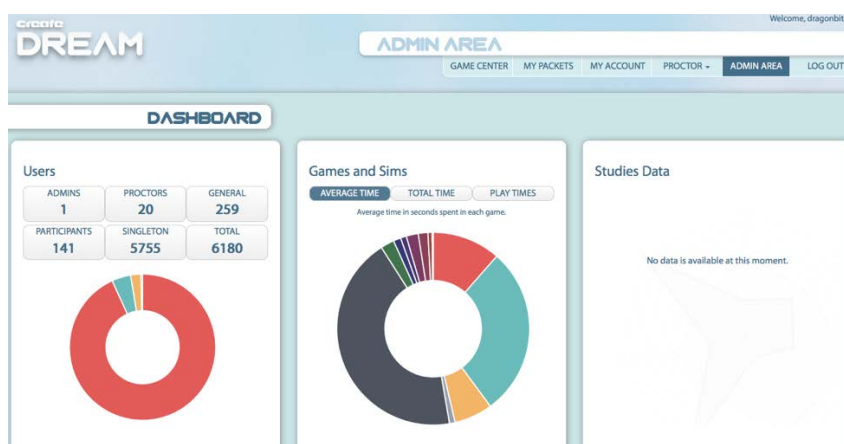
Figure 3. The DREAM dashboard.

At the symposium we will discuss how our research with teachers using games for formative assessment informed our design of the DREAM dashboard and will show how instructors can use the different views to inform their decision-making in class.

REALTO teacher dashboard to support the integration of school and workplace experiences

Beat Schwendimann and Mina Shirvani Boroujeni

Learners moving between different contexts, such as school and workplace, often struggle to integrate different learning experiences. As a result of the separation of different learning contexts, knowledge is often situated in one of these contexts and does not get used in others. The multi-context approach often leads to disconnected, inert, and fragmented knowledge that cannot be applied to solve problems. Our pedagogical model (Schwendimann et al., 2015) builds on the idea of capturing learning experiences to make them available for orchestrated reflection activities at a later time. The REALTO platform is being developed to support learners to capture, annotate, and share their rich experiences through different media (text, audio, photos, and videos) through mobile and desktop devices. REALTO aims to be a social learning space for sharing experiences across various learning spaces by connecting learners and teachers. Teachers can build on these captured experiences to integrate knowledge across context contexts by orchestrating different classroom activities. Two different elements of REALTO support teachers' classroom orchestration. First, interactive learning analytics dashboards allow teachers to monitor students' activities and identify patterns (Figure 4). Teachers can distinguish different engagement levels by tracking posts, comments, tags, and annotations. These indicators allow tracking student activities inside and outside of the classroom in real-time. Second, the REALTO notification system informs teachers (and learners) of new submissions, late submissions, and recent social annotations. Teachers can set up and track activities with deadlines. Research and development of REALTO aims to provide teachers with tools to orchestrate blended activities that support the integration of learning experiences from different contexts. REALTO is currently being used in several schools in a co-design process involving teachers, learners, and researchers.

As part of this symposium we will present audience members with samples of data captured within the REALTO platform to show how REALTO: 1) uses learning analytics to generate interactive visualizations that support teachers to monitor the class; and 2) can help teachers identify student engagement patterns in real-time.
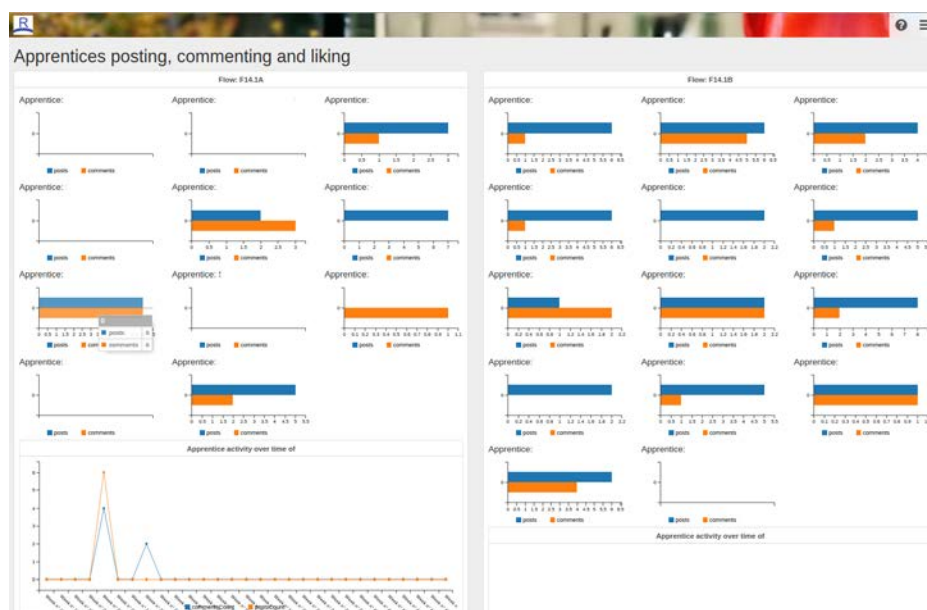
Figure 4. Real-time teacher dashboard showing learner's activities in an online environment (REALTO).

Supporting real-time teacher orchestration in a smart classroom setting

Mike Tissenbaum and James D. Slotta

There is growing interest in the learning sciences community in "smart classrooms" - technology mediated spaces in which the physical space itself becomes a mediator of student learning. In smart classrooms students are not simply browsing information passively, but are also creating, attaching, connecting, and taking data with them from one location to another, and from one group to the next. However, these immersive and interactive environments are likely to be more complex and dynamic than previous generations of computer supported learning environments (Slotta, 2010), placing additional load on teachers to track the milieu of actions taking place, the growth of students knowledge, and where and when they are most needed, most of which would be invisible or excessively time consuming for teachers to compile themselves (Tissenbaum & Slotta, 2013).

In order to understand the role orchestrational supports could play in such a curriculum, using the SAIL Smart Space (S3) architecture, we developed a specialized tablet application (Figure 5) that provided a teacher with control over the flow of activities and a real-time alert when he was needed. In order to provide the teacher with critical prompts and information, a central part of the development of this tablet was the development of intelligent software agents that could track the "state of the class" and respond to emergent patterns. In order to evaluate the effectiveness of the tablet application, we engaged four sections of high school physics students in a real-time smart classroom activity. When students reached a critical moment at the activity (as set by the teacher during co-design), an S3 agent sent a message to the teacher on his tablet to inform him he needed to review the group's work. He could then either approve the work and let them progress to the next step, or ask them to further refine their ideas and resubmit them. Across all four sections, the teacher approved the work of all 16 groups (four in each section), but asked six (38%) to resubmit their work for approval (with one group being asked to re-submit twice. To assess the effect of the teacher's reviewing and approving of groups' work on their final completeness score (a rubric co-develop with the teacher) we went back and rescored the work of all the groups the teacher asked to resubmit (i.e., before their edits). In total, the groups re-submitted seven times, resulting in an average change of .67 in their assessed score - indicating that alerting the teacher when and where to best intervene had a meaningful effect on groups' knowledge construction. As part of the symposium, this paper will discuss the design-based iterations that led to the teacher tablet application used in this scenario (including previous designs that were less effective for real-time interventions) and show video of the tablet being used by the teacher during the live smart classroom activity.
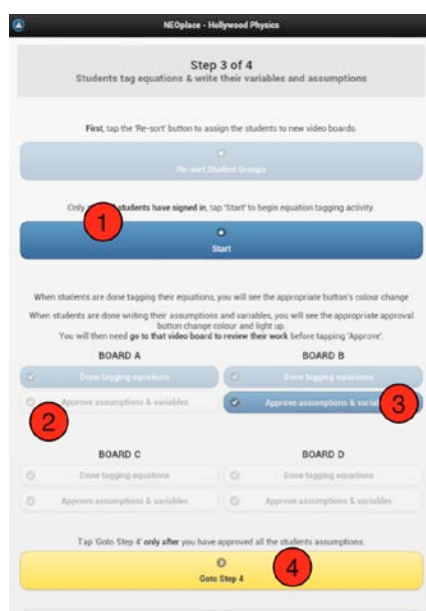
Figure 5. The Teacher Orchestration Tablet. The tablet (1) Enabled the teacher to start an activity; (2) Showed each group's progression through the activity; (3) Alerted the teacher when a group reached a point for intervention (pre-defined by the teacher); and (4) Let the teacher advance the class to the next step.

Visualizing data from automated scores to help teachers guide inquiry with scientific visualizations in diverse classes

Jonathan Vitale, Marcia Linn, and Libby Gerard

Inquiry-based science instruction promotes meaningful, self-directed student interaction with content. Teacher guidance helps students to make meaning from these interactions. Guiding struggling students who are working asynchronously can be a challenge for teachers. To help teachers determine which students would most benefit from their guidance, we have developed and tested a series of indicator tools within the Web-based Inquiry Science Environment (WISE). We use automated scoring for essays and concept maps to analyze student thinking and provide relevant visualizations to teachers to facilitate instruction. We have explored a series of visualizations of this data for teachers, including a progress monitor, student response viewer, and real-time alerts. In this demonstration, we detail the development and use of the real-time alerts (Figure 6) in diverse classrooms, drawing on data from classroom observations, teacher and student interviews, student science learning outcomes, and design iterations. We studied 6 teachers who used the real-time alerts in 3 schools with over 700 students. We compared different automated indicators of student progress to inform the alert system, including the time students spent on given activities, and the artifacts they generated. Additionally we compared teacher alerts to automated, text-based guidance. Results indicate that the teacher score-based alerts can be more effective than automated guidance, but require active teacher participation and high familiarity with student ideas. In interviews the teachers praised the teacher alerts and also indicated a desire for professional development to help them anticipate student difficulties and to plan guidance that facilitates inquiry. As part of this symposium, visitors will be invited to try the real-time alert system from both the students' and teachers' perspectives.

Figure 6. Left: The alert banner within the WISE environment. Right: The standard (top) and alert (bottom) banners.

Conclusions and implications of the symposium

This symposium comes at an important point in the learning sciences. Increasingly, learning interventions are infused with technology and bring with them new kinds of information that instructors need to keep track of and respond to in real-time. Despite this shift, there have been few frank discussions about what actually works and how instructors actually use the tools provided to them. This symposium brings together a set of projects that sit at the forefront of this research by examining the role that orchestrational technologies can play in highlighting patterns in student work, alerting instructors at critical moments in live activities, tracking student progress across formal and informal activities, and developing complex visualizations of student engagement and learning in real time. Through these examples, this symposium aims to advance the discourse and understanding of such supports and to provide a clear set of exemplar cases to support members of the broader learning sciences community in advancing their own designs.

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Researchers and Practitioners Co-Designing for Expansive Science Learning and Educational Equity

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Abstract: This symposium addresses the design and enactment of learning environments in support of the new vision for K-12 science education (NRC, 2012) and the related collaborative co-design practices of research-practice partnerships (Coburn, Penuel & Geil, 2013) as we focus on how to promote and understand cognitively and culturally expansive learning experiences for youth from culturally and linguistically diverse communities. Each study in our symposium is focused on "developing and testing innovations that can improve the quality and equity of supports for implementation of reforms" in real-world contexts (Penuel & Fishman, 2012, p. 282). The research projects in this symposium document practices and findings of various research practice partnerships that allow participants to work together to imagine and bring about new possibilities for educational improvement that reflect new goals and arrangements for learning. Our aim is to explore responsive co-design methods for collaborative design teams of researchers, teachers, and teacher leaders accountable for transforming student learning.

Introduction

This symposium brings together threads of research related to the design and enactment of learning environments in support of the new vision for K-12 science education (NRC, 2012) and the collaborative co-design practices of research-practice partnerships (Coburn, Penuel & Geil, 2013) as we focus on how to promote and understand cognitively and culturally expansive learning experiences for youth from culturally and linguistically diverse communities. We approach this work from an ecological perspective on how people learn within and across social settings as a strategy related to promoting educational equity and social justice (Bell, 2012).

In ideal terms, educational standards can be viewed as an equity-focused policy strategy for changing the educational system to ensure that all students have access to a baseline level of rigorous academic learning goals related to educational achievement. In pragmatic terms, standards-based implementation leads quickly to complicated problems of educational practice that need to be better understood and attended to. At of the time of this writing, the Next Generation Science Standards (NGSS) have been adopted by 17 states and the District of Columbia—with almost 35% of U.S. youth living in states working to support this new vision for K-12 science education. The new vision includes strategies and perspectives associated with cultivating culturally expansive learning opportunities for youth. There is a significant opportunity associated with working to promote those ideas at broader scale. Our work supports human capacity-building and educational tool development in STEM content areas and supports teachers within disciplinary-specific communities of practice, enabling equitable implementation of the NGSS, as envisioned in the NRC *Framework for K-12 Science Education* (NRC, 2012).

The learning sciences have long embraced collaborative design as a feature of design research (Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Voogt et al., 2015). Many of the NGSS implementation projects to be reported on are engaged in design-based implementation research (DBIR) with deep attention to systemic scaling and sustainability (Penuel et al., 2011), while others are engaged in traditional design-based research (DBR) to explore possibilities in specific settings (Bell, 2004). Collaborative design within research-practice partnerships presents both expanded possibilities and new challenges. Research-practice partnerships are long-term collaborations between practitioners and researchers that are organized to investigate problems of

practice and solutions for improving the outcomes of educational systems (Coburn, Penuel, & Geil, 2013). They have the potential for broader impacts, because designs aim to impact practice in larger systems and networks (Cobb, Jackson, Smith, Sorum, & Henrick, 2013). In addition, they have potential to develop important "context theories" related to learning (Cobb et al., 2003), focused specifically on the conditions for broad and equitable implementation of innovations. In addition, they require organizing partnerships to address concerns across multiple levels of systems and settings where differences of power and inequity deserve attention (Bang, Medin, Washinawatok, & Chapman, 2010). Our aim is to explore responsive co-design methods for collaborative design teams of researchers, teachers, and teacher leaders accountable for transforming student learning experiences.

Scholarly significance of the symposium

Co-design with teachers is intended to support cycles of expansive learning that transform the collective agency of teachers (Voogt et al., 2015). Working from an educational equity perspective, Guitiérrez and Vossoughi (2010) recently outlined an important new model of design-based research focused on exploring what is possible in learning environments using a grammar of hope, possibility, and resilience. In expansive learning, participants learn collectively by creating something that does not yet exist (Engeström & Sannino, 2010). Participants imagine and bring about new possibilities for action that reflect new goals and arrangements for learning. When they are able to "break away" from the give frame of action and take initiative to change it, their collective agency becomes transformative (Virkkunen, 2006, p. 49). To this end, we will take up social justice perspectives as we explore the co-design efforts of researchers and practitioners working to implement these NGSS-related projects.

Co-designing with teachers for student agency in science

Samuel Severance, William R. Penuel, Tamara Sumner, Wagma Mommandi, David Quigley, Katie Van Horne and Raymond Johnson

Curriculum materials that expand student agency can positively influence student affect, interests, and learning. Past research has found that units foregrounding student agency yield more positive affective responses from students (Morozov et al., 2014). In the context of long-term partnerships among researchers, educational leaders, and teachers, engaging teachers in the co-design of curriculum materials aims to transform the historical relationships of authority for curriculum while expanding student agency and learning opportunities (Penuel, 2014). When teachers co-design with researchers, however, student voices may be left out, and the team can miss opportunities to expand student agency in the design and implementation process. We elaborate on three strategies for soliciting student input into curriculum design and foregrounding student agency during co-design processes.

Teacher and student sample

Study data comes from 783 students of 13 teachers from 8 schools in a large urban school district in the Midwestern United States. Data were collected during the co-design of curriculum for high school biology. In this curriculum, 8-week project-based units are organized around a design challenge. These units are intended to embody the principles of the Framework (NRC, 2012) and address the performance expectations of the NGSS.

Strategies tested for promoting student agency in design and implementation

We employed three strategies to expand student agency within co-design processes and implementation: (1) linking the unit to larger community initiatives; (2) eliciting student interests in exploring different phenomena; and (3) using data on student perspectives on the design challenge and their classroom experiences.

Linking design challenges to larger community initiatives

We sought to enhance the likelihood that students would experience science as contributing to community by linking design challenges that anchored units to larger community initiatives. For the ecosystems unit, the challenge was to select and plant a tree that contributed to the biodiversity of the tree canopy and the life it supports in the city. This effort was linked to the city's tree planting initiative, which provided the recommended trees for the students to plant in collaboration with park department personnel. We assessed student interests and engagement with this design challenge using weekly mini-surveys administered throughout the 8-week unit implementation. For the majority of days in this unit, 65% of days (n = 1,225), students reported that the class' lesson was "relevant to their community," while 29% said the lesson was personally relevant to them.

Eliciting student ideas about phenomena

Project-based science units that embody the vision of the *Framework* need to be anchored in explaining phenomena in the natural world (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014). Not all phenomena are likely to capture and sustain students' interest, however. We designed a survey that asked current ninth grade students to rate their interest in 10 potential phenomena to investigate in the unit; they could also suggest alternative phenomenon. Teams chose to develop the design challenge around students' first choice and to develop supporting strands in the unit around students' other top interests. Initial surveys suggest that students perceive the selected topics as meaningful and relevant: in responses from two classes piloting this unit (n=110), 72% of students report that the class' lesson was "relevant to their community," while 36% said the lesson was personally relevant.

Using data of student perspectives

We gather evidence on a weekly basis on students' experiences of the challenge. This "practical measure" (Yeager et al., 2013) provides information to inform our iterative process of improving the intra-unit coherence of lessons. But the data we collect do more than hold us to account for coherence; they also include items about students' affective response to the unit, their judgment about whether what they learned that day was useful, and the personal relevance for lessons. Evidence shows we can still improve excitement and the perceived utility value of lessons, as 65% said what they learned on a given day was useful.

Implications

Student voice is challenging to integrate into collaborative design with teachers, but a concern with expanding student agency demands that we discover ways to incorporate student ideas into curriculum. We do so by connecting design challenges to community endeavors, eliciting student ideas about projects, and collecting data on student experiences of units that inform the design. These different strategies revealed a pattern of variation in student responses to curriculum but enabled the design team to strengthen efforts to expand student agency.

Co-designing a digital badge system: Supporting learners' science identities through participatory design

Katie Davis and Adam Bell

This study employed participatory design (PD) to develop a digital badge system that recognizes the skills and achievements of a diverse group of high school students who participate in an out-of-school science education program. Documentation of the design sessions illustrates the benefits of engaging students, program supervisors, and researchers in co-design activities aimed at articulating the learning pathways available to students in the program. By providing students with opportunities to reflect on their learning experiences, these co-design activities supported their developing science identities. This work offers best practices for directly engaging learners and supervisors in the design of a technology-based learning management system.

Conceptual framework and project design

This study is grounded in situated theories of learning, which emphasize the social, contextualized nature of learning. According to this perspective, learning is an inherently relational process that takes place as people negotiate meaning in specific social contexts (Lave & Wenger, 1991). Evidence of one's learning is similarly negotiated among actors who are embedded in distinct social systems, each with its own set of norms, values, artifacts, and practices. When new artifacts are introduced into a social system, there is an opportunity to call attention to existing practices and possibly alter them.

In the current study, students, program supervisors and researchers worked together to design a specific type of new artifact—digital badges—to recognize the learning that takes place in an out-of-school science education program. We employed a sociotechnological participatory design (PD) approach (Pazmino et al., 2015) that leveraged the expertise of the program supervisors and the researchers in order to focus student ideation for creating a digital badge system. Each design session incorporated one or more PD techniques informed by existing practice (e.g., rapport building, mixing ideas, stickies, layered elaboration) (Druin, 2002).

All PD sessions were recorded using a digital video camera and microphone. During the design sessions, researchers collected field notes that were later used for analysis (Merriam, 2009). Each session yielded design artifacts (photographed in situ). The analysis of the design sessions was completed in four phases: (1) after each design session, a researcher produced a narrative summary using a grounded theory approach (Merriam, 2009); (2) the researchers reviewed the summaries to identify critical events that occurred during each session (Derry, et al., 2010); (3) the researchers independently reviewed the video data corresponding to the critical events (Landis & Koch, 1977); and (4) the researchers viewed the critical events together for discussion and analysis (Bell, 2004).

Findings

By employing PD to create a digital badge system, students: *(1) articulated science knowledge* by displaying an understanding of science-related phenomena; *(2) constructed learning pathways* by mapping the structure of science domains; *(3) analyzed work practices* by stabilizing expectations for workplace success; and *(4) developed science identities* by embodying the epistemological orientation of science experts.

Implications of developing digital badges to promote STEM identities

This research offers evidence of successful sociotechnological participatory design with students as a method for designing a digital badge system and encouraging student reflection on their learning experiences. We show how PD techniques can be used to support the values and goals of an out-of-school, science-based learning environment. This project identifies the unique benefits of a digital badge system as a mode for wide-ranging

The co-design of professional learning experiences for teachers through a research-practice partnership

Philip Bell

In this design-based implementation research (DBIR) project (Penuel, et al., 2011), researchers partnered with staff from two urban school districts to support implementation of the vision of the NGSS and the underlying Framework (NRC, 2012). The partnership is focused on supporting approximately 100 teachers per year from these districts as they adapt, test, and refine existing instructional materials. I propose a model of design-focused research-practice partnerships (RPPs) called *lines of partnering*—and present an analysis of the co-design practices of researchers and practitioners conceptualizing, designing, delivering, analyzing, and refining professional learning experiences for this network of teachers.

Conceptual framework and study design

The partnership is engaging teachers in the adaptation of existing curriculum materials as the strategy for supporting teacher learning aspects of the new vision. This paper focuses on the co-design work of professional learning experiences for the teachers. We use the 'theory of persons' perspective to interpret human behavior as happening within a nexus of impinging structures of sociomaterial practice across places and over time (Dreier, 2009; Bell, et al., 2012). Partnering across practice communities is conceptualized as laying down and bringing *lines of action* into correspondence through the enactment of various sympathies (Ingold, 2015)—which are identified through empathetic investigations. In Design-RPPs, people interweave lines of activity related to the shared endeavor in the context of prevailing and generated forces from the nexus of social practices at play.

Six researchers partnered with six district staff and two staff from a science industry non-profit to engage in this work. Over three years the partnership has worked with 200 teachers from these urban districts to negotiate problems of practice associated with implementing the NGSS through curriculum adaptation. Ethnographic fieldnotes, audiorecordings, artifacts, and surveys were analyzed across multiple levels of the partnership (management, program design, program implementation, classroom).

Findings

I conceptualize such efforts as engaging in four different dimensions of necessary work—two of which are most relevant to this analysis. The shared work associated with *lines of purpose* involves inquiring into and articulating overlapping and synergistic goals for the collaborative work from multiple perspectives in ongoing ways. *Lines of collaboration and cooperation* involves taking programmatic action within such shared endeavors, together and apart, as practice-focused groups (e.g., to engage in co-design). Cross-cutting dimensions involve: *mutualism* by identifying sympathies in the work through empathetic stances, *pragmatism* by working within systems to transform them, *equity* by focusing on the learning of learners from non-dominant communities and by positioning teachers as developing experts, and orienting to *historicity* in the practices, values, and priorities involved.

Based on an analysis of the co-design work focused on the professional learning experiences of teachers, a range of findings have resulted at different levels of the partnership. *First*, political considerations of the work sometimes need to trump epistemological goals. Districts need scarce professional development projects to be successful. Setting pedagogical learning goals too high can result in teachers opting out and threatening the success of the effort. *Second*, teacher agency and leadership in the work is promoted by positioning teachers as developing experts doing meaningful work in educational improvement projects. Teachers report how curriculum adaptation allowed them to engage in meaningful work and leverage and expand their expertise in ways that served their immediate instructional goals and the goals of the broader educational organization. *Third*, co-design work within

the partnership led to emergent problems of educational practice that require unanticipated research-related expertise that the research team needs to develop and leverage from their professional network—in addition to the existing expertise they hold. *Fourth*, sustained partnerships between researchers and practitioners—with growing levels of mutual trust—allow for an increased exploration of values and ethics that relate to the shared co-design work from an equity perspective (Bang et al., 2015). A growing interest in promoting culturally and linguistically diverse students participation in epistemic practices resulted in co-design work foregrounding pedagogical discourse strategies for linguistically minoritized students as a leading project-level activity.

Implications

Our field has often operated through research-practice partnerships, but we have not adequately theorized and studied how they operate and influence educational improvement. Design focused research-practice partnerships represent a promising approach for building equity-centered human capacity and developing theory about professional learning as large-scale implementation unfolds within complex educational systems. The proposed model for partnerships as it relates to the co-design work of partnerships allows us to understand and cultivate more work of this kind centered on improving promoting equity in education.

The development of practical measures for teachers to inform the co-design of educational improvement efforts

Shelley Stromholt, Heena Lakhani, and Philip Bell

Through an ongoing partnership of educational researchers, practitioners, and STEM professionals, our work is focused on collaboratively adapting curriculum and developing relevant strategies and tools to support both teachers' and students' learning of STEM through engagement in disciplinary practices. We take a responsive approach to practitioners' curricular and collaborative goals and learning needs using design-based implementation research methodology (Penuel, Fishman, Cheng, & Sabelli, 2011). In this context we explore how practical measures can "act as sensing mechanisms at the level at which work is carried out," producing rich opportunities for identifying improvement targets and continuous learning (Russell & Grunow, 2015).

This study examines an approach for the co-design and implementation of practical measures, those that can be "collected, analyzed, and used within the daily work lives of practitioners" (Russell & Grunow, 2015) relative to a theory of implementation for a shared vision of K-12 science education and inclusive participation structures (NRC, 2012). This paper presents a case study of an effort to develop emic accounts of the productive approaches, problems of practice, and resulting design implications for professional development as teachers shifted their teaching toward practice-focused instruction through curriculum adaptation in response to the NGSS.

Conceptual framework and study design

In the context of improvement research, Bryk et al. (2015) distinguish *measurement for improvement* from other forms of educational measurement traditionally focused on accountability or theory development. Measurement for improvement entails the frequent measuring of high leverage work processes in order to inform change efforts in everyday practice. We leveraged an experience sampling approach, in which participants respond to a short survey about their immediate activities *in the moment,* frequently over several days or weeks (Zirkel, Garcia, & Murphy, 2015). This approach allows access to settings and experiences otherwise inaccessible to researchers and generates frequent and timely data that can be triangulated with other data sources related to the processes targeted for improvement. Through iterative co-design we developed a "mini-survey" for teacher reflection on classroom instruction and student engagement in disciplinary practices as instruction unfolded over the school year. As part of our research practice partnership, we then use the results to convey outcomes to our partners which informed subsequent interventions through professional development.

Sources of data

Teachers were surveyed weekly for 12 weeks over the 2015-2016 school year. We conducted a thematic analysis of the teacher responses using open coding to identify productive approaches and problems of practice teachers encountered at various stages of implementation across the school year. These results were compared with fieldnotes and other data collected as part of the larger research project to develop claims and design implications for effective professional development related to equity-focused, practice-focused instruction (Erickson, 1986).

Implications

A growing focus in educational research on learning in and through practice necessitates a focus on measurement for improvement, but there are few accounts of how research practice partnerships have engaged in development and implementation of practical measures and the resulting improvements. This case study offers insights into practical measures as an approach for blending rapid, disciplined cycles of inquiry with traditional research activities to inform our understanding of educational improvement.

Axiological innovations in an ArtScience participatory design experiment

Megan Bang

As we continue to try to understand the complexity of learning and development in the evolving "thrown-togetherness" of life (Massey, 2005) - which she describes as politics of the event of place including the politics of difference, identity, affect, connectedness and relations -- creating interventions that contribute to just and sustainable change demands engagement across disciplinary fields both within and across the social and physical sciences to develop new designs, narratives, and possibilities of encounter and making relations (Aitken, 2010). This paper examines the ways in which designers engage in epistemic navigation in the context of an ArtScience project called Expansive Meanings and Makings in ArtScience (EMMAS). EMMAS is a participatory design research project investigating the untapped potential of an ArtScience approach to learning and teaching. EMMAS aimed to foster creative trajectories into meaningful STEM learning for Native American youth. The project engaged community members, artists, scientists, and learning scientists to develop learning environments for youth and their families that engage investigate complex ecological change, interpret artistic and scientific visualizations, and respond creatively to questions by integrating scientific and artistic concerns, materials and processes. An artscience repertoire (cultivating attention, making, critique, and exhibition) underlies the learning experience.

Conceptual framework and study design

Building on Lave & Wenger (1991), EMMAS frames learning as a social phenomenon constituted in the experienced, lived-in world, through participation in the ongoing practices of social communities. As a creative movement, artscience highlights commonalities in thinking and making practices across social communities (Brown et al., 2011; Heath, 1986). Artscience emphasizes coming to know phenomena deeply—a process of making and re-making relations with phenomena, tools, materials, histories, and people (Ingold, 2013).

Using participatory design methods, specifically community based design (Bang et al., 2010) narrative, cognitive, and discourse analytic methods, I study the conceptual ecologies, identity narratives, and artscience repertoires that youth and designers develop through their participation in EMMAS inquiries. Data sources include 12 hours of video and transcriptions of program implementation and especially group conversations about juxtaposed artistic and scientific visualizations focus on students engaged in making artistic responses, interviews with 15 students, and 15 design meetings. All of the data were transcribed. The design of these programs intended to cultivate attention across multiple epistemologies, scales, modalities, and perspectives, using protocols that facilitated sustained engagement across multiple interpretive pathways, openness to emergent and uncertain meanings, and knowing as movement (Ingold, 2013) particularly as they related to complex ecological systems and students' cultural ecologies. Further community members were very interested in supporting students' sense of identity and community throughout the programming. Transcripts were initially open coded to identify emergent themes (Creswell, 2007). Drawing from this initial thematic analysis, moments of navigation were identified and further coded using critical discourse analysis (Gee, 2011). As part of this analysis I analyze the ways in which epistemic navigation and ways of knowing are constructed. I focus on how these constructions are both around disciplinary boundaries and expansions as well as around western and indigenous ways of knowing.

Findings

The findings of this study expand recent work on axiological innovations in learning environments (Bang et al., 2015). I argue axiologies are reflected in the theories, practices, and structures of values, ethics, and aesthetics that shape current and possible meaning, meaning making, positioning and relations in cultural ecologies. In this paper I work to uncover the ways in which axiological normativity is inscribed in moments when settled and often incomplete notions of disciplines are employed in design decisions and in implementation. I juxtapose these moments with interactions that "desettled" expectations and resulted in the disruption of axiological normativity and produce what I call axiological innovations. I specifically examine how these interactions reflect an artscience pedagogy and epistemic navigation across cultural ecologies. I track how students interviews reflect more nuanced and sophisticated understandings of complex ecological systems connected to the activities that accomplished

these more expansive axiological innovations. Specifically, students reasoned through problems in ways that reflected awareness of Massey's thrown togetherness and the need to attend to a valuing of diversity of life.

Implications

These findings suggest that deliberate work to cultivate axiological innovations in the design and implementation of learning may support ore equitable and expansive learning environments – particularly in participatory design contexts that engage a range of perspectives and expertise. Further the forms of ecological reasoning and problem solving reflect a kind of sophistication that reflects the demands of the 21st century.

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Teachers and Professional Development:
New Contexts, Modes, and Concerns in the Age of Social Media

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Abstract: The papers in this symposium together address new contexts, modes and concerns related to teaching and teacher professional development in the age of social media, with a particular focus on the socio-technical affordances and challenges of social network sites and teachers' perceptions and experiences. The presentations included in this symposium offer a multi-faceted and international view on the topic, highlighting both opportunities and challenges. Expected outcomes are a critical evaluation of the value, implications, and generality of the work presented to the field as well as an outlined agenda for future research on teaching with these new media and design work related to teachers' professional development.

Introduction

Symposium focus and issues addressed

Educational researchers and professionals have recognized the potential of social media, such as social network sites (SNS), to transform learning in and out of classrooms (Manca & Ranieri, 2012). Educational design initiatives have shown that engineered Facebook applications support discussion and knowledge building in informal (Greenhow et al, 2015) and formal learning settings through introducing informal elements (Tsovaltzi et al, 2014). However, we know less about teachers' perceptions, practices, and concerns related to teaching with these technologies or related professional development (Forkosh-Baruch & Hershkovitz, 2014). Indeed, the field has struggled to both understand the new cultures of learning arising in these "open environments" and connect them with educational practices that typically emphasize closed learning environments and teacher-centered pedagogies. We seek to make these connections visible through this synthesized set of papers. Symposium outcomes will be a better understanding of professional development in social networking sites as learner-empowering environments.

Online networking in social network sites (SNSs) like Facebook (FB), is the dominant technology-mediated, leisure-time activity among teenagers worldwide (Rideout, Foehr & Roberts, 2010). Most SNSs share common characteristics, including: 1) uniquely identifiable profiles that consist of user-supplied content and/or system-provided data; 2) (semi-) public display of connections that can traversed by others; and 3) features that allow users to consume, produce, and/or interact with user-generated content provided by their connections on the site (Ellison & Boyd, 2013, p. 7). Unlike studies in the learning sciences that have focused on isolated technology-based learning environments, open SNSs, generally not designed for instructional purposes, offer expanded vistas from which to study cultures of learning and teaching, mechanisms for teacher knowledge development and sharing, and ultimately, new modes for teacher learning and research opportunities.

In spite of their merits, SNSs are largely perceived in the public discourse as platforms for social interaction devoid of learning (Whiting & Williams, 2013). Educational policies restrict the use of SNSs, some even ban them, while others are vague and unhelpful. We propose a different approach – evidence based – focusing on the interaction between teachers and students as key for the effective usage of SNSs for learning; as a result, we will highlight in the symposium the need for incorporating SNS in teacher professional development and their exposure to the different aspects of SNSs in education, e.g. cognitive, emotional, social and ethical.

Significance to Learning Sciences and relevance to conference theme

This set of papers aims to provoke conversation on how learning scientists can advance timely, usable research that informs policy debates surrounding social media in education, as well as the design of teacher professional development (TPD). The papers explore a prototypical case of a social medium – Facebook. They employ observations of spontaneous Facebook use and controlled studies with engineered Facebook applications that blur formal and informal learning. They thus strive to understand with bottom-up and top-down approaches how social media influence the dynamic interaction between and role of the different stakeholders of schooling.

Range and coherence of papers

The papers in this symposium together scrutinize the use of social media in teaching and TPD. They address new contexts, modes and concerns of learning and teacher-student interaction in the age of social media, with a particular focus on the socio-technical affordances and challenges of social network sites and teachers' perceptions and experiences with them. Contribution 1, a review of a decade of empirical work, provides a 'state-of-the-field' viewpoint on learning and (preservice and inservice) teaching with SNSs. Building on this overview, the second contribution extends collaborative learning and argumentation theory to examine teachers' argumentative knowledge construction and development of communication skills in a field study of closed Facebook groups affiliated with a TPD seminar. The paper critically considers the best design for SNS-environments that advance professional communication as a compliment to traditional face-to-face TPD. The third paper compares teachers' perceptions of teacher-student SNS-mediated communication to that of students; it highlights their differences and raises critical issues that must be addressed in leveraging new media cultures for formal teaching objectives and in designing relevant TPD. Extending this work, the fourth paper examines whether and how secondary school teachers and students use SNS technology for learning and other school-related purposes *spontaneously;* it further illuminates the differences and potentially problematic contradictions in teachers' and students' practices and values that must be factored into TPD designs.

Symposium format

The symposium will commence by introducing the importance and potential of the topic. Next each contribution will be presented, emphasizing its key points and controversies. A central aim will be to evaluate and synthesize the different and overlapping perspectives represented in the papers. The discussant, Joseph Polman, a leading learning sciences researcher, has examined professional identity and the design of new media environments; he maintains a critical view of current assumptions regarding learning and teaching with social media and is, therefore, aptly suited to help us assess the value, implications, and generality of the work presented to the field and sketch an agenda for future related research on learning and teaching and design work related to TPD.

Learning and teaching with social network sites: A decade of research in education

Christine Greenhow and Emilia Askari

The increasingly widespread use of social network sites to expand and deepen one's social connections is a relatively new but potentially important phenomenon that has implications for teaching, learning and TPD in the 21st century. This paper reviews the educational research, including a scan of over 1600 identified articles to present the state-of-the-field and provide a launching off point for the symposium's additional three papers. This paper reviews empirical work on learners and teachers' perceptions and processes of using social network sites in K-12 settings and beyond with what impacts on pedagogy, students' learning, or TPD.

Method

To illuminate the potential benefits and dilemmas of designing educational practices with new media, such as social network sites, a select review of research articles published in refereed journals between 2004 and 2014 was undertaken. Boote and Beile (2005) outline several categories to which the reviewer must attend in conducting a quality literature review, such as: coverage (having criteria for inclusion and exclusion); synthesis (summary, analysis, and synthesis of selected literature); and significance (discussion of the implications of the existing research). A first criterion was that the article had been published in the last 10 years (2004-2014). A second criterion for inclusion was that the article had been published in peer-reviewed journals dedicated mostly or entirely to the topic (i.e., technology integration/Internet in education) or in high quality general education journals (e.g., *Review of Education Research*, *Journal of Learning Sciences*, etc.). Because a scan of these journals yielded few results, the scan was expanded, using Scopus, ERIC, Education Full Text and Web of Science databases to identify additional peer-reviewed articles published from 2004 through 2014.

From the range of potential articles, an initial content analysis was conducted to separate them into the following categories: description, literature review, empirical research, and editorial/commentary, while excluding specific article types like book reviews and research abstracts (Klein 1997). Because this review was primarily concerned with the state of empirical research, studies that were more conceptual in nature or those with little evidentiary support were excluded. In addition, articles that focused on social media generally, but did not address social network sites specifically, were eliminated. To establish the quality of selected articles, empirical articles needed to demonstrate: (1) clear statement of research questions; (2) claims and interpretations grounded in evidence and theory; and (3) systematic documentation of procedures (Freeman, deMarrais, Preissle, Roulston & St Pierre, 2007). Our scan of selected journals and database queries yielded a total of 24 empirical peer-reviewed journal articles deemed appropriate for review.

Results and discussion

Five themes were evident in the reviewed studies ($N = 24$); the studies focused on: students' informal learning outside of school; students' formal learning in schools and classrooms; connections between in- and out-of-school learning; and preservice and inservice teachers' perceptions and practices. Furthermore, selected studies were summarized and categorized according to the four types introduced by Roblyer (2005) as studies most needed to advance the technology in education sub-field. These include studies that establish the technology's effectiveness at improving student learning; investigate implementation strategies; monitor social impact; and report on common uses to shape the direction of the field. The most prevalent type of study conducted was research on common uses and studies that investigated implementation strategies in formal learning settings. The least common type of study was research that established the technology's effectiveness at improving student learning and several studies did not fall within the framework. Implications for the design of future research and teacher education initiatives are discussed (See Greenhow & Askari, 2015 for the full review).

Using social networking sites to support teacher-trainees professional development: The role of socio-cognitive conflict and argumentation

Dimitra Tsovaltzi, Thomas Puhl, and Armin Weinberger

Social media like SNS can empower lifelong professional development. They are often spontaneously used by teachers as platforms for professional discussion as they seek professional development that goes beyond applying appropriate subject-matter teaching methodologies. Study programs also offer seminars to this end, e.g. to improve teachers' communication skills. They commonly teach communication theories in order to influence teachers' communication attitudes and communication skills. However, attitudes tend to be stable (Erber, Hodges, & Wilson, 1995) and teacher trainees have pronounced negative attitudes towards the need for good communication skills (Ihmeideh & Al-omari, 2010). Attitude change presupposes long-term deep learning and conflict awareness (Erber, Hodges, & Wilson, 1995). Deep learning can be obtained through Argumentative Knowledge Construction (AKC), which is the deliberate practice of elaborating learning material by constructing formally and semantically sound arguments with the goal of gaining argumentative and domain-specific knowledge (Weinberger & Fischer, 2006). SNSs may offer a platform for socially embedded argumentation processes that can lead to socio-cognitive conflict and seize benefits for the teacher-student interaction in social media and beyond. However, the argumentation quality in SNSs can be poor and alternative perspectives are regularly disregarded. Can incorporating SNS in TPD help teachers improve their knowledge about and attitude towards communication skills?

Scripts are socio-cognitive structures that specify, sequence, and distribute learners' roles and activities in collaborative learning scenarios, e.g., by prompting learners to warrant their claims. Scripts can improve processes and outcomes of argumentative knowledge co-construction (Weinberger, Stegmann & Fischer, 2010). *Group Awareness Tools* (GATs) aim to foster domain-specific knowledge by visualizing covert information about the group — e.g., highlighting conflicting opinions in discussions — and can enhance the collaboration process, like socio-emotional and motivational processes (Buder & Bodemer, 2008). While GATs can make learners aware of their own and their partners' attitudes, thus making differences salient, scripts can help analyze lines of ongoing argumentation and model adequate argumentative processes. GATs rely on high self-regulation skills that empower teacher-learners but may be too subtle, whereas scripts externally regulate argumentative practices but may be too directive. Their interaction over time may help teacher trainees deeply analyze the domain, elaborate alternative perspectives, scrutinize and maybe adjust them.

Method

In a long-term 2×2 field-study, with factors GAT and argumentation script, we used Facebook, a prominent SNS, to complement face-to-face teacher training seminars on communication theory with online argumentative discussions over 9 weeks. 105 German teacher trainees filled out a weekly case-based questionnaire, to capture their communication attitudes based on cases from social interactions in the school. Each seminar was accompanied by one Facebook group, where students had to discuss problem cases based on the theories they learned. The seminar's leaning goals were that teacher trainees gain deep knowledge on communication theory and in turn, become more multi-perspective and less goal-oriented, but keep a balanced attitude based on the situation. Students in the GAT conditions saw a graphical visualization of the result of the communication questionnaire presented in a Facebook application. It depicted their communication attitude in relation to others' reported attitudes in order to make conflicts salient. Students in the argumentation script conditions received a weekly argumentation script in the form of feedback to arguments posted in the Facebook group. They had to pick and "like" the best argument. The feedback evaluated the epistemic (theoretical concepts and relations) and the formal (reasoning and evidence) argumentation quality for two selected arguments. Participants in the control condition merely discussed in their Facebook group. Domain-specific knowledge was assessed by the course exam containing definitions, facts, and higher order discursive processes like theory-based interpretations and arguments. Process analysis was based on epistemic and formal quality of arguments using an adapted version of Weinberger & Fischer's framework (2006). Attitudes were measured with the communication attitude questionnaire along two dimensions, as revealed through factor analysis (Puhl, Tsovaltzi, & Weinberger, 2015): multiperspective vs. goal-oriented.

Results and discussion

A repeated measures ANOVA showed a significant effect for the interactions between time with epistemic quality, $F(6;606)=3.81$; $p<.001$; $\eta_p^2=.10$, and with formal quality, $F(6;606)=1.88$; $p=.015$; $\eta_p^2=.053$ Descriptive statistics show that the epistemic quality did not change for the control group but increased for the argumentation script. Formal quality also increased only for argumentation script and decreased for the control group (Figure 1). An ANOVA for domain-specific knowledge showed significant main effects for the factors GAT, $F(1;98)=11.24$; $p=.001$; $\eta_p^2=.10$, and argumentation script, $F(1;98)=23.44$; $p=.001$; $\eta_p^2=.19$, and an interaction between them, $F(3;102)=4.89$; $p=.029$; $\eta_p^2=.05$. The control learned less, $M=34.08$, $SD=6.53$, followed by the GAT, $M=39.81$, $SD=5.42$, the argumentation script $M=41.34$, $SD=4.38$, and the combination condition, $M=42.52$, $SD=4.33$. The domain-specific knowledge correlates with mean of epistemic quality of arguments over the eight times $r(102)=.29$, $p=.03$, and the mean of formal quality of arguments $r(102)=.36$, $p<.001$. When we take the influence of these process variables on domain-specific knowledge into account in an ANCOVA, there is a significant effect of condition, $F(1;3)=7.07$; $p<.001$; $\eta_p^2=.18$.
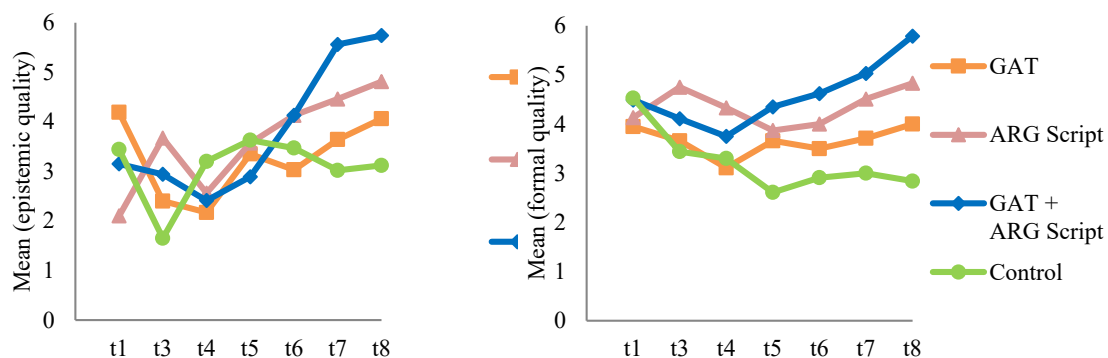
Figure 1: Epistemic and formal quality of argumentation (weekly measurments)

Using a repeated measures ANOVA, we found a significant main effect on communication attitude change over the seminar period for the goal-oriented dimension, $F(8;800)=14.2$; $p<.001$; $\eta_p^2=.12$, which showed decreasing attitudes, but no significant effect for the multi-perspective dimension, $F(8;800)=2.87$; $p=.003$; $\eta_p^2=.02$, or for the interaction between time and group. Descriptively, attitudes increased on the multi-perspective dimension for the combination condition, and post-hoc contrast showed a significant difference to the argumentation script only condition $t(100)=2.35$; $p=.023$; $d=.64$. There was a negative correlation between attitude change in the two dimensions $r(104)=-.28$, $p=.003$, and between the significant change in the goal-oriented dimension and the knowledge outcome $r(101)=-.24$, $p=.016$.

The GAT and the argumentation script, implemented in Facebook, influenced teacher-trainees' knowledge outcomes and increased the argumentation quality. The argumentation script had a larger influence, but its combination with the GAT showed the best results. Scripts seem to be more promising regarding formal quality of argumentation, although both formal and epistemic quality influences knowledge outcomes. The negative correlations of attitude change with knowledge outcomes are in line with the learning goals of the seminar. The results reveal benefits of combining cognitive instructions, in the form of scripts inside a Facebook group, with making learners aware of socio-cognitive conflict in order to self-regulate their argumentation, gain deep knowledge and re-evaluate their attitudes given a longer time period. However, contrary to the positive influence on knowledge outcomes, the combination of salient socio-cognitive conflict and cognitive directions for argumentation in SNSs seems less beneficial for assuming a more multi-perspective attitude. Thus, the desired effects of empowering teacher-learners' meaningful professional discussion in social networking environments might be dependent on the learning goal and learning context.

Teachers' and students' perceptions of positive and negative aspects of SNS-mediated communication: Implications for professional development

Arnon Hershkovitz and Alona Forkosh Baruch

Today's young people have outpaced educational policies and institutionalized practices, creating digital epistemologies and out-of-school learning opportunities for themselves with social media while educators and policymakers struggle to catch up. Teacher-student relationships are generally believed to be vital for the well-being and academic development of students within schools (Sabol & Pianta, 2012); however, many educational stakeholders express ambivalence regarding the value and implications of teacher-student communication on social networking platforms, which typically extend beyond school boundaries. On the one hand, teachers are encouraged to recognize students as whole entities, addressing not only their academic achievements but also their emotional lives, social needs and general well-being (Moll, Amanti, Neff, & Gonzalez, 1992). On the other hand, teacher-student communication on SNSs—(where students display social, emotional, academic and other aspects of themselves) (Greenhow & Robelia, 2009)—has been prohibited in many countries and school districts. Research that advances understanding of the positive and negative aspects of teacher-student, SNS-mediated communication may yield insights that assist educators and teacher educators in designing TPD opportunities that promote the critical evaluation of practice and policy necessary to address this gap.

Method

In two quantitative studies, launched in 2013-2014 with teachers (*N=180*) and students (*N=667*) from secondary schools in Israel, we examined teachers' and students' perceptions of the positive and negative aspects of teacher-student interactions via Facebook, collected via open-ended response questions. Responses to questions about positive aspects were coded based on Ang's TSRI axes (2005), specifically: Satisfaction and Instrumental Help (a single statement could have been coded by more than one axis). Responses to questions about negative aspects of teacher-student, Facebook-mediated communication were analyzed following a bottom-up approach, identifying categories of reference. This iterative process was done jointly by the two authors and resulted with seven categories, as described in the next section.

Results and discussion

Examples below refer to teachers' responses to the following question: "In your opinion, what are the downsides of teacher-student connections on Facebook?"

1. **Technology and Socio-Technology**. "A teacher will never be able to know what stands behind the kid's words on Facebook, because what the kid says is, in most cases, false, and you can only know it by the kid's body language." (T267)

2. **Violation of Equal of Opportunities**. "Breaking anonymity. [Also,] not all the teachers are connected [to Facebook]." (T144)

3. **Lack of Borders**. "The option of getting into each other's personal aspects. Crossing borders " (T156)

4. **Identity and Anonymity, or Inappropriate Behavior**. "Endangering the teacher by blaming her or him in an instance in which a student posts negative information—such as violent content, drugs/alcohol, depression and suicidal tendency—on knowing about it and not intervening" (T34)

5. **Teacher-Student Relationship**. "Facebook ruins the morality and the purity of the teacher-student relationship" (T95)

6. **Exposure to Information and Privacy**. "The teacher will be radically exposed to his students, especially with regard to his personal and family matters." (T99)

7. **There Are No Negative Aspects**.

Quantitative analysis of the responses to the aforementioned question is demonstrated here. This question was answered by 507 students and 170 teachers. Note that a single student's response could have been coded under multiple categories. Results are summarized in Table 1.

Table 1. Comparison of frequencies of categories for teachers' and students' responses regarding negative aspects of teacher-student, Facebook-mediated communication

	Teachers (N=107)	Students (N=507)	Z, Effect Size
Technology and Socio-Technology	2 (1.2%)	24 (4.7%)	2.09*, r=0.08
Violation of Equal of Opportunities	3 (1.8%)	33 (6.5%)	2.38*, r=0.10
Lack of Borders	69 (40.6%)	82 (16.2%)	6.61**, r=0.27
Identity and Anonymity, or Inappropriate Behavior	22 (12.9%)	89 (17.6%)	1.41
Teacher-Student Relationship	46 (27.1%)	90 (17.8%)	2.62**, r=0.11
Exposure to Information and Privacy	86 (50.6%)	227 (44.8%)	1.32
There Are No Negative Aspects	12 (7.1%)	57 (11.2%)	1.56

* $p<0.05$, ** $p<0.01$

Results show significant differences between teachers' and students' perceptions regarding four categories. Students mentioned more equal oppportunity aspects than teachers (6.5% compared to 1.8%, Z=2.38, at p<0.05); also, students mentioned more technological/socio-technological aspects than teachers (4.7% compared to 1.2%, Z=2.09, at p<0.05). On the other hand, teachers mentioned the lack of borders more than students did (40.6% compared to 16.2%, Z=6.61, at p<0.01); also, teachers mentioned relationship issues more than students did (27.1% compared to 17.8%, Z=2.62, at p<0.05).

Studies of SNS-mediated communication out-of-school have established Facebook's affordances for enhancing students' sense of social belonging, well-being and life satisfaction (Ellison et al., 2007; Greenhow, Burton & Robelia, 2011), all of which could be beneficial to their academic persistence, achievement and graduation. However, differences in teachers' and students' perceptions of teacher-student, Facebook-mediated communication help surface disruptive (or transformative) issues that must be considered when leveraging new media cultures for formal learning aims (e.g., lack of boundaries and inability to verify information pose challenges to the teacher's role as source of authority in the classroom) (Maranto & Barton, 2010). SNS-based communication pose ethical dilemmas (Chen & Bryer, 2012); hence, related teachers' professional development should include exposure to actual ethical dilemmas and debate on resolution. Finally, these results suggest that policymakers should consider diversity within the teacher community, as well as among students, in their perceptions of teachers' role (e.g. academic roles, social roles, roles related to emotional support).

Teenage knowledge sharing in WhatsApp and Facebook groups

Christa Asterhan and Edith Bouton

Educational researchers and professionals have recognized the potential of SNSs to transform learning and teaching practices, inside and outside classrooms. Educational design initiatives have shown that specifically developed Facebook add-ons can support knowledge building and discussion in informal (Greenhow et al, 2015) and formal learning settings (Tsovaltzi et al, 2014). However, we know little about whether and how secondary school teachers and students use SNS technology for learning and other school-related purposes *spontaneously*. Research shows that teenagers and secondary school teachers interact in SNSs. Some of these teacher-pupil interactions serve social-relational purposes (Asterhan & Rosenberg, 2015; Hershkovitz & Forkosh-Baruch, 2013). Others serve psycho-pedagogical purposes, such as adult patrolling and monitoring of the virtual social sphere or detecting and providing emotional support for individual emotional distress (Asterhan & Rosenberg, 2015; Ophir et al, submitted). Some teachers also report that they use SNSs for instructional purposes (Asterhan & Rosenberg, 2015). There is then reason to believe that teenage students also use ubiquitous SNSs for academic and school-related purposes, yet little is known about these practices. This paper presents findings from a multi-method line of studies that highlight different aspects of teenagers' WhatsApp and Facebook groups for learning, study, and other school-related purposes, and the role of teachers in these groups, if any.

First, we conducted an exploratory pilot study, which included in-depth interviews with teenage students from different high schools in Israel (Bouton & Asterhan, 2013) and about 50 logged transcripts of SNS study group interaction. Based on these two data sources, we concluded that online peer-to-peer dialogue on academic content and other forms of "collaborative learning" was extremely rare. In fact, teenagers' spontaneous use of SNSs for academic purposes was primarily characterized by *peer-to-peer sharing* of learning materials. Sharing of knowledge is a very broad term, especially in the digital age, when documenting, copying and distributing knowledge and knowledge sources is easily done (John, 2012). Knowledge sharing has been studied extensively in fields such as business management (Acquisti & Gross, 2006), organizational counseling (Tsai, 2014) and economics (Taylor, 2002). However, peer sharing of schoolwork and learning materials has not received much attention in educational research. While *sharing and discussing ideas* is viewed as a cornerstone of learning (e.g., Resnick, Asterhan & Clarke, 2015), *sharing learning materials* is often viewed as an inferior form of cooperation, promoting superficial learning strategies.

In the next two studies, we then set out to further explore the different ways in which teenagers share knowledge for school-related purposes in SNS study groups. The overall aim was to answer six "W" questions: the *whether*, *where*, *when*, *what*, *why* and *who* of peer knowledge sharing in SNS study groups. To this end two survey studies were conducted in the Fall of 2014 ($N = 205$; 41 items, 11 open items) and Spring of 2015 ($N = 517$; 91 items, 7 open items) on two different representative samples of Israeli, Hebrew-speaking teenagers aged 15-18 *yrs* old. We summarize the main findings of the two studies combined:

- *The scope of sharing, or whether?* Most teenage students (86%) reported being members of SNS study groups in either Facebook or Whatsapp or both (88% in > 1 group). Almost all teenagers admitted to having shared at least "some learning materials" during the school year and believed that it helps improve grades. Four-fifth of respondents regarded the use of SNSs for schoolwork purposes favorably.

- *Where do they share?* Most respondents (86%) chose WhatsApp as the most convenient SNS platform for study groups, while 6% preferred Facebook . Three quarters of teenagers who are members in SNS study groups reported that their teachers are members of at least one of these groups.

- *When do they share?* Interestingly, most teenagers indicate that they do not share without being asked first by one of the group members (64% for own sharing, 81% for sharing by others).

- *What do they share?* Based on the pilot study findings, we distinguished between five different types of knowledge sharing for school-related purposes: (1) administrative messages, (2) snapshots of whiteboards and other teacher-created materials, (3) student-created summaries (of lessons or reading), (4) copying of homework and other assignments (i.e., cheating); and (5) online peer tutoring and learning. Teenagers reported that they frequently encounter administrative messages, snapshots and peer learning in SNS study groups, and significantly more so than copying or student-created summaries ($p <.001$). We also asked them what type of shared materials they themselves use most. Responses showed that they use administrative messages more than any other type ($p <.003$), except for peer learning.

- *Why do they share?* Based on student responses to open items in the first survey study, six different motives for sharing were identified: helping others to succeed, improve positive self-concept, quid pro quo (secure receiving help in future), gaining social stature, and lack of effort. In study 2, self-identified knowledge brokers (central sharing figures in their own SNS groups) indicated that the most frequent motive for sharing was to help classmates to succeed, and least frequent motive, to gain social stature.

- *Who are the sharers?* Regression models showed that cooperative-collectivistic views, self-efficacy and mastery learning goals predicted teenagers' knowledge sharing in SNS study groups. No correlation was found between competitive-individualistic views and sharing. Amongst students who do not endorse a quid pro quo motive, competitiveness was negatively correlated with sharing behavior, whereas a positive correlation was found for those who believe in future pay-offs of sharing.

In the fourth we conducted interviews and focus groups with 86 teenage students from a range of backgrounds to better understand the workings of WhatsApp SNS groups in classrooms. We highlight one main finding relevant to this symposium topic: many teachers initiate official "classroom Whatsapp groups" which they believe encourage civil communication (because of adult presence) and improve group cohesiveness (Bouhnik & Deshen, 2014). However, our findings reveal that in addition to these formal groups, which are mainly used for teacher-led communications, students open "shadow" groups, excluding the teacher and without

his/her knowledge. Often, these include a subset of students, usually excluding less popular kids, are considered more important and active, and provide a podium for critiquing what happens in the "official" groups.

Based on the four studies presented here, we reach several conclusions. First, teenage knowledge sharing in SNS study groups is a widespread phenomenon, primarily through WhatsApp. Second, sharing administrative messages and snapshots are the most common types of knowledge sharing, but online peer help-giving and help-seeking is also present. While the first two types of learning materials are mundane, the third type holds the most promise, may be "upgraded" by giving students better tools and guidance on how to improve peer learning interactions. The findings also indicate that existing concerns about SNS study groups as hotbeds of cheating (i.e., share homework solution, exams) and study shortcuts (i.e., relying on others' summaries) proved to be only partly founded. Finally, teachers should be aware of the existence of student-initiated, self-organized SNS shadow groups in their classrooms, which have quite different sets of norms and goals. Future research should compare our findings to additional student and teacher populations, track student and teacher behavior in real-time and focus on what individuals do with all these shared learning materials.

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Posters

Enjoyment and Satisfaction as Details for Kinetic Learning

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Abstract: In this paper, we investigated the role of Enjoyment and Satisfaction in Kinetic Learning. We conducted an experiment in which half of all participants were asked to perform a physical activity congruent with the learning content (Kinetic condition), and the other half were asked to use a website interface to simulate the performance of the activity (Non-Kinetic condition). Our results showed that the Kinetic condition produced significantly higher learning performance than the Non-Kinetic condition, together with higher Enjoyment and Satisfaction levels. These results suggest that Enjoyment and Satisfaction may contribute to an increase in student learning performance in Kinetic Learning by providing additional detail and meaning for association with the learning event.

Introduction and related work

Kinetic Learning is a theory that physical movement or experience can help enhance learning outcomes by stimulating the sensorimotor system of the brain, as this adds detail and meaning to students' thinking (Kontra, Lyons, Fischer, & Beilock, 2015). It has been shown that touchscreen physical gestures congruent with the learning content can help boost cognition (Segal, 2011).However, it is unknown whether the same learning enhancement extends to full-body movement, and what the affective factors actually are.

In this paper, we investigated how full body movement enhanced learning performance, from the affective aspects of Enjoyment and Satisfaction. We achieved this by comparing the effects of Kinetic Learning facilitation against Non-Kinetic facilitation on learning performance, Enjoyment and Satisfaction.

Methodology

In order to compare the effect of Kinetic facilitation against Non-Kinetic facilitation, we first created a learning support system in the form of an online tutorial website. This tutorial website was designed to teach the topic of web-based sensor programming, based on the Sensorendipity smartphone sensor programming platform (Lu et al., 2014). The tutorial was framed in the form of a story. The story's protagonist was a PE teacher who wanted to know if his students were performing enough jumping jacks at home, and the tutorial user was the PE teacher's assistant tasked to create a web-app, to be installed in students' smartphones, to keep track of the amount of jumping jacks that they performed every day. The tutorial facilitated this learning through videos, step-by-step guidance on how to break down the jumping into parts, and tools for choosing the most appropriate smartphone sensors to achieve the goal.

In our study, we wanted to examine the effect of Kinetic verses Non-Kinetic learning facilitation. Therefore, several variables were kept constant, such as learning content and presentation method, and the tutorial website was viewed through a laptop. The only variable that manipulated was the way in which users interacted with and progressed through the tutorial.

For the Kinetic facilitation, users were required to physically perform jumping jacks while having their smartphones in their pockets, thereby embodying the conditions in the story. The physical movement would then be captured through the smartphone (preloaded with Sensorendipity app), and the movement would then be represented on the laptop screen as an animated jumping figure, accompanied with a bar graph that represented the level of movement (low, medium, high). Therefore, the physical movement controlled the website animations.

Based on the data generated by the jumping, as animated onscreen, users would then type into a part of the tutorial website information about which sensors to use and why. This information entry then allowed users to progress forward in the tutorial. For the Non-Kinetic facilitation, the users saw the exact same visuals, but they did no need to jump with the smartphone. Instead, the website controlled the animations on its own. In this way, the audio and visual content was kept exactly the constant between the two learning facilitations.

Evaluating learning impact

We designed the following experiment to evaluate the learning and affective impacts of the two learning facilitation methods. Twenty volunteers (Mean age 23.3, SD= 1.2, 8 female), with no prior programming experience, participated in the between-subjects study.

The independent variable was that of learning facilitation method (Kinetic / Non-Kinetic). Half the volunteers were assigned to the Kinetic condition, and the other half were assigned to the Non-Kinetic condition. The dependent variables were Enjoyment as measured using a survey (Lin, Gregor, & Ewing, 2008) that was administered immediately after the completion of the tutorial, and a Satisfaction rating (measured using a five-point Likert scale [1: Highly Dis-satisfied, 5: Highly Satisfied) was administered as a question after the Enjoyment survey. Finally, learning performance was measured using a post-activity quiz administered twice; once immediately after the Satisfaction rating [Week 1], and once after a week of the activity [Week 2]. The Enjoyment survey and Satisfaction rating were administered before the quiz in Week 1, so that the quiz difficulty would not affect the other dependent variables.

Results

Using independent samples t-tests, we compared the quiz scores from the Kinetic and Non-Kinetic conditions, and found a significant difference (t[18]=-3.069, $p < .01$). Participants in the Kinetic condition scored significantly higher in the Week 2 quiz than their Non-Kinetic counterparts. There was no significant difference for Week 1 quiz scores. In terms of Enjoyment, there was a significant difference (t[18]=-2.198, $p < .05$), with the participants in the Kinetic condition exhibiting higher Enjoyment levels than participants in the Non-Kinetic condition. In terms of Satisfaction, participants in the Kinetic condition rated the activity significantly higher than participants in the Non-Kinetic condition (t[18]=-2.151, $p < .05$). Using Pearson Correlation analysis, we found that Satisfaction was strongly correlated with Enjoyment ($r = .665$, $p < .01$). There was no significant correlation between quiz scores and the other dependent variables.

Discussion and conclusion and future work

As the results suggest, we can conclude that the Kinetic condition produced significantly better learning performance than the Non-Kinetic condition. However, this performance enhancement was only apparent one week after the activity. This suggests that Kinetic Learning facilitation seemed to have provided effects that lingered long after the activity was completed, thereby resulting in better retention of information after a week. This result agrees with previous work (Kontra et al., 2015), and might therefore be the consequence of the stimulation of the sensorimotor brain systems that Kontra et al. alluded to.

The effect of this Kinetic stimulation also resulted in increased Enjoyment, which could be attributable to increased Positive Affect (Lin et al., 2008). As defined by Lin et al., Positive Affect can be described as the feelings of pleasure, happiness, contentment, or similar emotions. It is also clear from the data that Satisfaction was greater in the Kinetic condition.

The results support the conclusion that Kinetic Learning facilitation can stimulate the sensorimotor regions of the brain, and produce Enjoyment and Satisfaction in the learning experience. In turn, these emotions form part of the detail and meaning that students can associate with the learning experience, and this association has been shown to improve retention of the learning content.

Future work will be to expand on the types of Kinetic facilitation, as only a specific type of Kinetic Learning was studied here. Also, more studies may be needed to study the long term effects of Kinetic Learning.

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Acknowledgments

Reforming the Undergraduate STEM Classroom Experience

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Abstract: In this poster we present the initial design of a faculty professional development program at a research-extensive university that leverages learning sciences research to support STEM faculty in the use of active learning techniques to improve engagement and learning. Our goal is to transform the common instructional practices of STEM faculty by addressing challenges symptomatic of large enrollment, entry-level courses and to engender a community of practice that emphasizes reflective teaching at the research university.

Although extant learning sciences research on STEM learning and teaching has mainly focused on K-12 settings, the challenges adult learners face in post-secondary settings are highly similar to those faced by youth (e.g., Bao et al., 2009). While the underlying mechanisms responsible for these trends are the subject of much debate, several researchers have proposed that existing curriculum frameworks and pedagogies in university settings are insufficient at providing students with the most basic cognitive and practical skills necessary for scientific literacy (Kramer, 2011). These studies show that current pedagogical models that emphasize teaching STEM content as an isolated body of facts in large lecture settings without relevance outside of classroom contexts are ineffective for most students. Moreover, university curriculum materials that rely solely on lectures with little classroom interaction leave students with a poor understanding and little opportunity to engage in authentic scientific practices. Here, we present the initial effort at the University of Illinois-Chicago to address these challenges that leverages research in the learning sciences to frame a design-based research project focused on faculty professional development.

Modifying university curriculum and instruction is not intractable as empirical evidence has shown that changes in faculty pedagogy to create a classroom environment that is more interactive can improve both student achievement and persistence (Freeman et al., 2014). Those techniques that have been seen to be most effective include *active learning pedagogies* as well as assessment practices that include frequent feedback to students on their learning. Recent innovations in educational technology have been developed to support active learning techniques by relocating traditional "information transmission" approaches of a lecture to online platforms. Using such technologies, instructors can use class time for more engaging pedagogies. By increasing peer-peer and peer-instructor interactions in the classroom, students receive increased opportunities to engage in scientific argumentation and inquiry practices as modeled by STEM faculty. Engaging students in this way improves students' motivation to learn and increases their motivation to pursue a STEM career (National Research Council, 2005).

Surprisingly, individual instructors and STEM departments have been slow to adopt active learning pedagogies, particularly in high-enrollment, lower-division courses. Similar to secondary school settings, the primary barriers to curriculum reform efforts in post-secondary settings include insufficient professional development opportunities for faculty and a lack of institutional resources to support curriculum development and modification (Henderson, Beach, & Finkelstein, 2011). Although STEM faculty often use active learning pedagogies on an ad hoc basis, few institutions have implemented large-scale reform efforts to train faculty to use or to evaluate the impact of such techniques on student learning or retention. It is not sufficient to mandate that instructors make use of engaging classroom activities without comprehensive and sustained professional development. To address this need, we have developed a professional development program that engages faculty in rigorous practice-based learning opportunities (Ball & Cohen, 1999) and an iterative curriculum development process (Reiser et al., 2000).

The program includes an initial two-day summer workshop followed by 3-hour bi-monthly workshops, for a total of 5 workshops in a given academic year. The initial two-day workshop first provides an overview of known challenges to learning in undergraduate STEM fields identified in the STEM education research literature, research on implementing active learning techniques, principles of formative assessment, and strategies for providing undergraduate students with feedback in the classroom. All subsequent bi-monthly workshops are divided into two parts, with an ongoing dual focus on influencing faculty beliefs about teaching and learning in ways that reflect robust disciplinary learning and fostering a collaborative environment around the implementation of active learning pedagogies and development of supporting curriculum resources. The first part involves the use of instructional artifacts (e.g., student work samples, inquiry-based problems, classroom video), during which

faculty participants have opportunities to engage with the ideas generated from discussions of the artifact. The second part provides faculty opportunities to consider the ideas generated from the discussion in relation to their own practice, including planning for upcoming classes and interacting with other faculty participants around the workshop ideas. Importantly, participants in each cohort share their experiences and developing expertise with subsequent cohorts through a structure that supports sustained interaction among overlapping cohorts. Our aim is to create professional learning opportunities for faculty to systematically explore what it means to learn with understanding in their respective disciplines, anticipate potential strategies and misconceptions students may encounter, envision plausible instructional strategies that can be employed to effectively support learning, and consider ways to model scientific thinking and problem solving with a focus on content, active learning, coherence, and outcome measures (Garet, Porter, Desimone, Birman, & Yoon, 2001).

To help support the reform of entry-level STEM courses and the implementation of active learning pedagogies across multiple departments, we also help faculty to develop, implement, and evaluate active learning curricular modules. For this work, participating faculty collaborate in the professional development program and with their department head to create a module for an entry-level course that includes both online and in-class activities. First, the program staff work with each faculty member to identify a learning obstacle in a lower-division course and develop a curricular module that addresses this obstacle. This module is individually tailored to the course and might include a lesson, group activity, inquiry investigation, or online component. Next, the faculty member drafts the module in collaboration with program staff and a discipline-based education research assistant. The department head and program staff then review the material and provide recommendations for revising the material to ensure that it makes use of active learning pedagogies and is responsive to departmental needs. With a complete module, the faculty member enacts the revised module in the classroom. During implementation, project staff visit the classroom and observes the module in use. Using videotaped data and field notes, the staff documents instructor and student difficulties with each activity, as well as constraints, such as resources and time. Feedback is then provided to the faculty member with recommendations for revising the module. After final revision the module is ready for uptake by other course instructors and it is deposited into a digital repository available to all STEM faculty.

Numerous studies have demonstrated the benefits of active learning pedagogies, but the impact of such methods in many disciplines remains outstanding. Lead advocates for undergraduate STEM education curriculum reform have noted that many STEM faculty are delaying adoption of these models as they wait for evidence that such practices can improve outcomes in their specific discipline (Mervis, 2013). Our efforts to effect institutional change in STEM instruction at the University of Illinois-Chicago are based on similar efforts at the University of Colorado-Boulder and elsewhere and represent a concerted effort to establish the efficacy of active learning in multiple STEM disciplines concomitant with case studies of effective implementation, both of which are needed if the approach is to achieve widespread adoption.

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Design of Automated Guidance to Support Effortful Revisions of Science Essays

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Abstract: This study compares two approaches to improving student effort in response to automated guidance in an online thermodynamics unit, either a focus on revisiting evidence or planning writing changes. While the revisiting group made more revisits to suggested visualizations and the planning group made more substantial writing changes, the revisiting group ultimately made greater score gains. Findings suggest that prompting students to explicitly consider revisiting evidence can improve effortful use of guidance and learning outcomes.

Introduction

In this study, we seek ways to present guidance that supports students to engage in effortful revision strategies. Automated guidance based on the knowledge integration (KI) framework for science learning prompts students to reconsider and distinguish between scientific ideas on their own, rather than verifying the accuracy of student answers or telling them to try again (Linn, 1995). Because knowledge integration guidance requires students to engage in difficult activities such as considering ideas simultaneously and exploring additional investigations, some students may feel discouraged and avoid the task (Chaiklin, 2003). In previous iterations of our web-based inquiry thermodynamics unit, over 50% of students did not add a new scientific idea to their initial response after receiving automated guidance.

To increase student effort in response to automated guidance, directing focus onto explicit tasks that students can complete may augment feelings of agency. Agency is defined as the power to take meaningful action and see results from one's decisions and choices (Basharina, 2013). In this study, students' agency is supported by focusing students on the explicit consideration of one of two strategies they can use in the revision process. Revisiting previous evidence (Gerard et al., 2015) and planning writing changes (Rivard, 1994) are two well-documented strategies for improving scientific explanations through revision. The two guidance conditions in this study allow us to examine the impact of revisit focused versus planning focused guidance on student revision strategies and understanding of thermodynamics concepts.

Methods

This study included 177 students from two teachers' sixth grade science classes in a suburban middle school with a moderately diverse population. 54% of students in the school were of non-Caucasian ethnicity and 31% received free/reduced lunch. Students completed the thermodynamics unit in the Web-Based Inquiry Science Environment (WISE; http://wise4.berkeley.edu). This study focused specifically on a step called Spoons, where students submitted a 2-3 sentence response that was scored by c-rater™, a natural language processing model built based upon previous students' responses and corresponding human scores on a KI rubric. Students were immediately assigned guidance corresponding to their KI score level, and prompted to make immediate revisions to their response.

In this study, all students receive conceptual KI guidance based upon their initial automated KI score on Spoons. All KI guidance referred to students by name, prompted them to consider new information or asked about a missing concept, provided a link for them to revisit a relevant earlier portion of the unit, and asked them to revise their response. To promote agency, after receiving KI guidance, students were randomly assigned to focus on either revisiting evidence or planning writing changes and asked a multiple choice question regarding their intended actions for revisiting or plan for writing. The multiple-choice question was intended to draw attention to and promote agency surrounding these two strategies, in an attempt to increase student effort and improvement in revision.

Students' initial and revised responses to the Spoons automated guidance question, as well as pre and posttest items, were scored on a KI rubric. Analysis investigated whether learning gains in the embedded Spoons item and the pretest to posttest scores differ by focus condition, as well as to determine if the two different focus conditions impact high vs. low prior knowledge students differently. To evaluate students' effort in revision strategies, log files were examined to determine whether students revisited the prior unit step suggested by KI guidance. Students' initial and revised Spoons responses were compared to examine their revision characteristics.

Findings

Students in the revisit focus condition made significantly greater KI score gains from initial to revised response than students in the planning focus condition [$M_{revisit}$ = .405 KI points, SD = .671; $M_{planning}$ = .210 KI points, SD = .452; t(126) = 1.87, p < .01] (Figure 1). Students' initial scores on the pretest or on Spoons did not significantly predict the effect of guidance condition on gain scores, which suggests that revisit guidance was more helpful for students across all initial knowledge levels.

Results also validated the effect of focus condition implementation on student effort in strategy use. Students in the revisit focus condition were more likely to revisit the step suggested in KI guidance than students in the planning focus condition [X^2(1, N = 126) = 6.98, p < .001] (Figure 2).

Just as students in the revisit condition were more likely to revisit evidence in the unit, students in the planning condition were more likely to make a substantial writing revision to their essay. Students who added either a normative or non-normative scientific idea were classified as having made a substantial change. Changing some words in their answer, but without adding a full idea, was classified as minimal change. The distribution of revision characteristics was significantly different across conditions, suggesting that the planning focus does encourage more students to make effortful revisions. However, more effortful writing changes did not necessarily translate into score improvement. While students in the planning focus condition were more likely to add ideas, they added non-normative ideas as often as they added normative ideas.
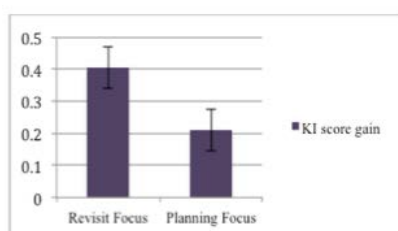
Figure 1. Average KI score gain from initial to revised Spoons response, by focus condition
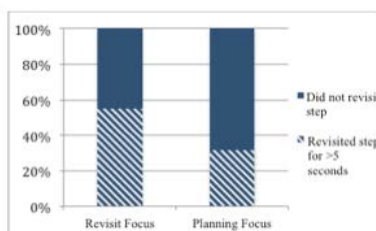
Figure 2. Revisiting pattern by condition
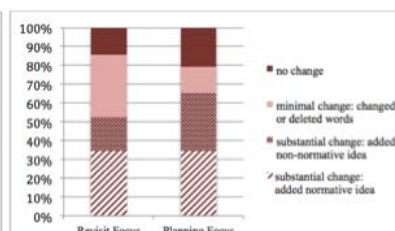
Figure 3. Revision characteristics by condition

Conclusion

While automated guidance can help students improve essays in science, not all students make effortful revisions. To encourage students to make an effort to improve their essays, we compared two foci for revision. The two conditions operated as planned in that more students revisited with the revisit focus and more students modified their writing with the planning focus. Additionally, the revisit focus condition showed greater improvements in response to guidance than those in the planning focus condition. The task of revisiting a previous step may have seemed more concrete and tangible to students, and thus students in this focus condition may have been more motivated to improve their answer than those who received a more abstract and possibly overwhelming focus on planning writing changes. Providing students with strategies that have been found to be successful, while also supporting their agency, can be a promising way to improve student approaches to learning that can be generalized to multiple contexts.

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Engineering Real-time Indicators for Targeted Supports: Using Online Platform Data to Accelerate Student Learning

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Abstract: Statway® is designed to accelerate students' progress through their developmental math sequence to acquiring college math credit in statistics. A recent causal analysis confirmed the effectiveness of Statway. However, there exists room for improving student success by focusing on the first of the two-course sequence. The objective of this paper is to formulate indicators from self-report and online learning system data, alerting instructors to students' progress during the first month in the first course.

Introduction

The objective of this paper is to describe our efforts to formulate a practical system of indicators available during the first month of the course to alert instructors to students in need of targeted interventions. The focus of our analysis is Statway, a year-long two-course sequence developed to address complex problems that impede student success in developmental math. A causal analytic study with a multilevel propensity score approach confirmed that Statway dramatically improved student success in half the time (Yamada & Bryk, in press). However, a recent study (Sowers & Yamada, 2015) suggests that there is still room for improving students' success in Statway. The analysis focuses on factors that may contribute to student failure in the first course. Our analysis leverages existing data from different sources and develops early indicators to inform instructors whether students need additional support (Yeager, Bryk, Muhich, Hausman, & Morales, 2013). We know that engagement early in the course (attendance, accessing supporting materials, engaging in regular homework contributes to student success.. In this study, we leverage three sources of data. First, self-report survey data is used to measure productive persistence, a set of non-cognitive factors thought to affect community college developmental math student success (Yeager et al., 2013). A second source of data assesses students' mathematical conceptual knowledge (MCK), which contributes to gains in procedural skill, and not vice versa (Boaler, 1998). Because existing math placement tests assess procedural skill almost exclusively, it is important to understand the conceptual knowledge (or lack thereof) of students entering Statway. Lastly, we use data from an online learning system, such as accessing readings, homework practice, and assignment completion, to define students' engagement (U.S. Department of Education, 2013). Our goal is to integrate these non-cognitive, conceptual math, and behavioral data into an efficient system of indicators.

Methods

For the analysis of this paper, data were available from a total of 1344 students who enrolled in 58 sections of Statway across 21 colleges in Fall 2013. Self-report data on productive persistence were collected during the first days of the course. Measures used were fixed mindset (belief of math ability as fixed), stereotype threat (negative group stereotypes regarding math achievement), belonging uncertainty in class, comfort asking questions in class, and professor cares (perception of the level of instructor caring about student success in class). The first two concern students' self-perceptions as math learners and doers, and the latter three are related to their perceptions of their classroom setting as a mathematical learning environment. The fixed mindset item was a 6-point scale of endorsement. The other items were on a 5-point scale. We dichotomized each indicator into *at-risk* and *not-at-risk* based on prior analyses. Data on MCK were also collected during the first week of the course. The MCK consists of 21 items, measuring key constructs identified as impediments to developmental students' math learning: fractional and decimal values, proportional reasoning, basic algebraic notation, and reasoning about the effects of mathematical operations. Based on Rasch analysis (Wright & Masters, 1982), we differentiated students into three conceptual knowledge levels: low (6 or fewer out of all 21 items correct), middle (7-14 items correct), and high (15 or more items correct). Statway courses in Fall 2013 used Carnegie Mellon's OLI platform. OLI provided data on practice quizzes and graded checkpoints (end of unit assessments). We defined at least one attempt as engaged and formulated the level of engagement: 6 levels for practice quizzes (no attempts, ~30% engaged, ~60% engaged, ~80% engaged, ~99% engaged, and fully engaged) and 4 levels for checkpoints (no attempts, ~60% engaged, ~99% engaged, and fully engaged). First, we applied latent class analysis (Agresti, 2002) to data on productive persistence and MCK to formulate student patterns. Online data accumulated over a month were submitted to latent class analysis to develop different engagement patterns in practice quizzes and

checkpoints. At each time point we calculated a course success rate per student segment to see how success rates changed. Success was defined as a grade of C or higher.

Findings and implications

Table 1 presents change in success rate during the first month by student segment (with the number of students in parentheses). We formulated 4 distinct patterns from Time 1 data. If students showed high MCK and low risk productive persistence during the first week, they would have a highest likelihood of success in the first Statway course (87%). The next two groups were differentiated by the level of productive persistence and accordingly difference in success could be expected. The last group was characterized as not engaged because they did not complete MCK or survey items on productive persistence. Those success rates estimated during the first week were increased or decreased, depending on the level of engagement with the online platform at Time 2. If students attempted all practice quizzes and checkpoints, their success would further increase (95%). It appears that full engagement with checkpoints and some engagement with practice quizzes helped the last 3 student groups increase their success rate, while some engagement with both in fact decreased it. Non-engagement dramatically decreased the likelihood of success rates. What is puzzling is the result from students with no engagement at both times. We may need to see more data beyond the first month for this student group and other student segments with the lower rates. In addition to this investigation, we plan to validate our findings against data from Fall 2015 in which we had a much better control over data collection with the newly developed portal, more feasible data retrieval from the online learning system, and more student data. Accordingly, we expect to utilize data beyond the first month of instruction to refine our indicator. Our aim is to establish the best practices for integrating different sources of data over time to identify students in need of targeted interventions.

Table 1: Success rate over time by student segment

Time 1 (during the first week)		Level of online engagement at Time 2 (after the first month)			
		Full with both	Some with practice quizzes Full with checkpoints	Some with both	No engagemen
High MCK/low risk productive persistence (326)	87%	95% (127)	86% (136)	80% (54)	33% (9)
Middle MCK/low risk productive persistence (540)	70%	90% (157)	74% (224)	50% (127)	28% (32)
Middle MCK/high risk productive persistence (200)	64%	85% (46)	71% (94)	38% (55)	20% (5)
No engagement (278)	59%	88% (17)	78% (65)	41% (32)	51% (164)

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Acknowledgments

A Design Research to Support Elementary Students' Epistemic Understanding of Their Scientific Argument Construction

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Abstract: This study examined an instructional design to improve the scientific argument of elementary students by enriching their epistemic understanding of scientific argument. The proposed instructional design was an iterative approach that included instruction of epistemic criteria, argument construction, peer review, and teacher's feedback on students' arguments. Analysis of students' utterances in peer reviews and the argument construction task revealed that students acquired epistemic understanding and improved their scientific argument through the instructional design.

Introduction

Research that investigates instruction for scientific argument is progressing in the research field of learning sciences (e.g., Andriessen & Baker, 2014). Epistemic understanding of scientific argument refers to the understanding of criteria met by good arguments. Although there is some evidence that students' argument construction is influenced by their epistemic understanding of scientific argument (Ryu & Sandoval, 2012), almost no instructional design that can enrich students' epistemic understanding has been proposed.

The aim of this study is to examine an instructional design to improve the scientific argument of elementary students by enriching their epistemic understanding of scientific argument. This study embodied the epistemic understanding of scientific argument as the following criteria: appropriate and sufficient evidence that supports the claim, and justification that connects the evidence to the claim using scientific principles (Zembal-Saul, McNeill, & Hershberger, 2012). This study adopts the methodology of design research called conjecture mapping (Sandoval, 2014). Referring to this idea, the following two research questions were addressed: (1) whether the instructional design as an *embodiment*, enriches elementary students' epistemic understanding of scientific argument as *intended mediating processes*, (2) whether the instructional design as an embodiment improves elementary students' scientific argument construction as the *desired outcomes*.

Methods

Participants and instructional design

The participants were 38 fifth-graders in elementary school in Kobe, Japan. In the "How Things Dissolve" science unit, the properties of a liquid solution were elucidated using experiments and experimental presentations (13 sessions, 45 minutes each). Four exercises were conducted. In each exercise, the teacher briefly taught the epistemic criteria of scientific argument, specifically how to express each component of argument, that is, claim, evidence, and justification. Students constructed arguments about their verification experiments in accordance with the epistemic criteria that had been instructed, and then shared their arguments to engage in peer review. The teacher also provided correction and feedback. The fourth exercise focused on constructing an argument by selecting appropriate evidence from multiple scientific facts.

Data source and analytic methods

During peer review, students spoke about the quality of their partner's argument based on the criteria for good arguments to their knowledge. Students' discourse during peer reviews was recorded with IC recorders and transcribed. To capture students' epistemic understanding, we developed a coding scheme, referring to Ryu and Sandoval (2012). Only codes of epistemic criteria are shown on the left side of Table 1.

The argument construction task was conducted before and after instruction. Students were asked to write an argument about scientific content (germination and ice) that differed from the content of the unit. For each item, six experimental results were provided as evidence; three were related to the relevant principle, and three were unrelated. Students' written arguments were broken down into claim, evidence and justification, and were scored using a rubric reflected the epistemic criteria described above. A perfect score was eight.

Findings

Intended mediating processes

The number of students who said something corresponding to each criterion was counted. The right side of Table 1 shows the occurrence rate of utterances for the students overall. In order to clarify the mediating processes, the number of epistemic criteria students mentioned was compared between the first peer review as a baseline and the later assessments. The baseline average number of occurrences for the four criteria excluding "appropriate evidence" was .71 (SD=1.04) and 1.74 (SD=1.18) in the third peer review. A t-test showed a significant increase in the criteria mentioned ($t(34)=5.253, p<.001$). The baseline average number of occurrences for all five epistemic criteria, including "appropriate evidence," was .89 (SD=1.10) and 2.06 (SD=1.47) in the fourth assessment. The t-test showed a significant increase in the criteria mentioned ($t(34)=4.527, p<.001$).

Desired intervention outcomes

Figure 1 shows the mean argument scores for each item (germination and ice). For both items, argument scores improved from the pre-test to the post-test ($t(37)=1.705, p<.10; t(37)= 3.635, p<.001$).

Table 1: Code of epistemic criteria and rate of appearance of utterances (%)

code	description	1st	2nd	3rd	4th
Claim	Responses to the task	25	37	39	34
Justification 1	Use scientific principles	14	25	47	39
Justification 2	Coordinate the evidence to the principle	17	6	36	50
Sufficient evidence	Use of multiple pieces of evidence	19	31	61	53
Appropriate evidence	Include unnecessary evidence	11	—	—	22
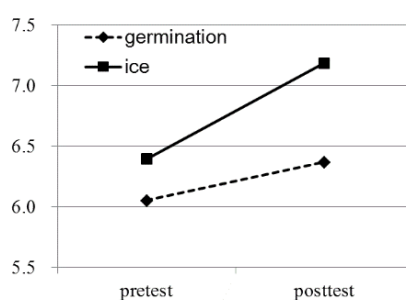
Figure 1. Mean argument scores for each item in the argument construction task.

Conclusions and implications

The above results demonstrate that the instructional design in this study, iterative approach using epistemic criteria, enriched elementary students' epistemic understanding of scientific argument as an intended mediating process, and also improved elementary students' scientific argument construction as in the desired outcomes. This study also demonstrated that protocol analysis of peer reviews was promising as a method to measure students' epistemic understanding. Further studies are required to examine the relationship between mediating processes and outcomes through analysis of the remaining data.

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Acknowledgments

Journalistic Sources: Evaluation in Third Space

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Abstract: This study investigates how students analyzed the civic perspectives they gathered in a journalism program designed as a third space. Preliminary findings indicate that students drew from multiple social voices, engaging with heteroglossia, as they brought both journalistic (taught in class) and exogenous (from other contexts) sources into their classwork. In doing so, they made moves to better contextualize these sources on geographic, scalar, and ideological dimensions.

Introduction

In this study, we look at a civic youth journalism program designed as a third space (Moje, et al. 2004; Gutiérrez, 2008) – aimed simultaneously at teaching students journalistic practices while positioning their everyday experiences as resources. We seek to understand how young people analyzed the perspectives they gathered as part of journalistic work. Inherent to journalistic practice is engagement with heteroglossia, or the multiple social voices of the world (Bahktin, 1981). This study highlights the ways journalistic practices provided youth opportunities for gathering and evaluating diverse sources, and the affordances of a third space environment for supporting students' agency to adapt, extend, and transform traditional journalistic practices.

Literature review

Through media production, youth have the opportunity to communicate their personal and political perspectives to the larger world (Rheingold, 2008; Goldman, Booker, & McDermott, 2008). The professional journalism practices ask that producers gather and orchestrate a variety of social perspectives in the form of the *sources* they report (Lam et al., 2015). As such, we argue journalists necessarily engage with *heteroglossia* (Bakhtin, 1981).

One particular practice of journalism is that of *source evaluation*, in which a journalistic source—for example, an interviewee, an official report, another journalistic text—is evaluated to decide whether and how information from that source should be included in the story. Doing this often means considering a source's societal authority; thus, we find elite, official, and while male sources dominating forms of news coverage (Carlson, 2009).

Education researchers have proposed the design of *third space* as a way to support young people in learning new practices, while also challenging and transforming them (Moje, et al. 2004; Gutiérrez, 2008). Third space pedagogies help us think about how we might teach the powerful but problematic practices of journalistic source evaluation, and keep students from replicating the stratification between the voices students find in heteroglossia. In classrooms, this often means that practices from students' everyday lives are leveraged as resources towards entering and transforming disciplinary practices.

Methods

We developed a 5-week curriculum to teach journalistic production within a non-profit organization located in a low-income, urban community. Fifteen Black, Hispanic, and mixed-race high school-aged students worked in teams to produce short documentaries. We drew from third space theories (Moje et al., 2004; Gutiérrez, 2008), to address the challenge of asking students to take up practices from a profession that often misrepresents their communities. To that end, we developed curriculum that 1) promoted engagement with heteroglossia through the journalistic practice of source evaluation; 2) positioned sources from students' own community as valuable, authoritative, and worthy of consideration; and 3) positioned students' personal experiences and engagement with media as resources.

The first author played a dual role as teacher and researcher, facilitating the curriculum and collecting field notes, video recordings, and student work. At the end of the program, the first author conducted directors' commentaries with each student group, which involved watching students' documentaries together, stopping after each cut and discussing students' choices. We identified several *classroom events* in which students and the teacher engaged in the practice of journalistic evaluation to transcribe and code closely (Bloome, et al., 2005). These events were then further broken into journalistic evaluation episodes, beginning when a participant introduces a new source of information from journalistic interviews or past experiences to discuss. We selected 3 events to analyze closely.

Preliminary findings

Students in the program were expected to gather information from family, community and institutional sources, as understanding a range of views on an issue is essential to journalistic evaluation. Therefore, students in the program were guided to conduct journalistic interviews, which the teacher introduced and practiced with them. The types of sources they interviewed as part of this guided journalistic curriculum included interviews with friends, family, with people from their own and another neighborhood, and with an activist from UOA. In discussions of these journalistic sources, students also drew from exogenous sources, information gathered in their day-to-day lives. These sources included experiences with family and friends, but also with school and media. Students' introductions of exogenous sources led to deeper conversations that related students' experiences with the perspectives they gathered as journalists. Particularly, in evaluating both journalistic and exogenous sources, students leveraged their prior experiences and knowledge to *contextualize* the information they obtained as journalists. Contextualization involved asking where the source comes from, what it might represent, and how it compares to other similar sources on different dimensions, particularly geographic, scalar, and ideological. For example, Angelica and Oliver created a short documentary on the recession and youth employment. They had observed that in just looking at their neighborhood's "poverty" and the city's downtown that "you wouldn't even know" it's the same place. This exogenous source led them to seek to contextualize the experience of joblessness across communities. In conducting interviews, they said only one person in their own community had a job, compared to everyone they interviewed downtown. In such instances of contextualization, students connected their own experiences with journalistic work to better make sense of the ways in which context shapes the perspectives offered by sources.

Conclusion

These early findings suggest that journalism is a generative context for engagement with heteroglossia, with students evaluating a variety of both journalistic and everyday sources. This, coupled with positioning students' community sources and experiences as valuable, authoritative, and worthy of analysis, helped build third space, in which students picked up and hybridized practices taught in the curriculum. This suggests, then, that third spaces pedagogies attend not only to meaning-making practices that support young people in thinking with and across discourses, but particularly in considering their scalar, geographical, and ideological dimensions. We intend to further iterate on the curriculum, with particular support for contextualization.

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Using Video Recording Glasses to Get a First Person Perspective

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Abstract: This poster discusses methodological potentials and limitations concerning the use of video recording glasses to capture students' first person perspective on class activities.

This poster reports initial methodological findings concerning the use of video recording glasses to capture students' in situ first person perspective on class activities. The glasses make real time recordings of whatever is looked at by the student wearing the glasses. They simultaneously record auditory input around the student. The glasses can thus be used to show, literally, a first-person view of the situation. Our research questions are:

- RQ 1: How can video recording glasses contribute to the collection of in situ data? What are the potentials and limitations as compared to stationary or researcher held video cameras?

- RQ 2: What areas within research on motivation and learning will be informed in new ways through data obtainable only by using video recording glasses?

The second author has used the video recording glasses in several studies in classrooms and museums. Recordings were made with two pairs of Pivothead Durango glasses. They record full HD video, have 77 degree field-of-view optics, and an integrated microphone, http://www.pivothead.com/technology/originals/.

To illustrate our preliminary findings, we present a narrative based on a recording with the glasses. The glasses are worn by Jon and Ed. Jon sits with Dan at a computer with an online science learning program. They have just finished a task on European countries and open the next task on the screen. Names are pseudonyms.

> ***Narrative:*** *Initially, Jon looks at the task on the computer screen. Dan sits partly visible at the keyboard. Dan makes some comments concerning how to solve the task. Jon is quiet. After 30 seconds, Jon starts looking about the room, prompting reactions from fellow students. He says "Yeah" to a girl who smiles back. He calls to Ed, waves and gets a wave back. After 45 seconds, he focuses on another group's screen. It shows the website geoguessr.com. Jon calls to the group "Hey, how do you do that" but gets no answer. He calls "Bob, you can't guess that". He then asks Dan "should we do this?" Dan answers "I'll do it shortly". Jon calls the group once more, then moves over to them; looking at the screen all the time. He says "Habibi, I asked how do you do this". They answer and proceed with their geoguessing. Jon stays with the group for the rest of the film (24 minutes). They do geoguessing for the entire period.*

We look first at RQ1. According to Derry et al. (2010), four sets of challenges are present for researchers who collect and use video to conduct research in complex learning environments: 1) *Selection*, which refers to deciding how to place cameras; when to start and end recording; whether to record wide angle or close up; and whether and how to pan and zoom. 2) *Analysis*, concerning choice of analytical framework and practices. 3) *Technology*, which concerns software for video analysis; technologies for video sharing among researchers and in reports of research; metadata schemas; and so on. 4) *Ethics*, referring to legal and ethical issues. Our findings concern 1) and 3) as the analysis and ethics concerns we have noted do not differ from those reported by Derry et al. for video in general. Jordan and Henderson (1995) similarly point out two limitations of video recording. A) *Limits of the operator*, and B) *Limits of the technology*. A) refers to the operator's focusing of the camera on one object instead of others, corresponding to the *selection* issue raised by Derry et al. Focus will invariably be influenced by the operator's notions of what is/is not significant. We propose that this bias can be minimized by utilizing video recording glasses worn by the students. As illustrated in the narrative, the recording selection is made by the students themselves, by what they look at, in the flow of action. The use of video recording glasses does not eliminate selection bias, however, because the researcher chooses students to wear the glasses (subject to student accept). The sequence in our narrative would e.g. not have been captured, had another student been chosen. Thus, an obvious methodological issue is the selection of which students' first-person perspective to capture. Selecting *fairly* to represent culturally prototypical cases of practice is significant (Derry et al., 2010).

The *limits of the technology* for the glasses concern memory size and battery power. Due to their size, the glasses have obvious limitations compared to a standard digital HD video camera. The built-in flash memory can only store around one hour HD video (8 GB). Fully charged glasses have power for about one hour's recording. Downloading 8 GB data to another device takes around 15 minutes. Recharging takes over an hour. The glasses are thus not useful for prolonged recordings. In the narrative, the battery ran out before the end of class. In consequence of this limit, we do not know whether Jon ended up returning to his partner, Dan, or not.

Henderson and Jordan (1995) further discuss how the presence of a camera affects people. In our 10 years' experience with classroom video recording, students habituate to the camera surprisingly quickly, especially if there is no operator behind it. Our preliminary findings indicate that this goes for students wearing the glasses, too, and that they do not constrain their gaze to whatever they are supposed to look at (e.g. the task). In the narrative, the student thus only looks briefly at the task on the screen. Still, students do become aware of the glasses once in a while e.g. if they are annoyed by the fit. The student's hand may then be seen to move toward the camera (to adjust the fit). The narrative suggests that Jon is aware of the glasses some of the time, e.g. when he calls to the girl and to Ed. Other students may become aware of the video recording when they see their classmates look different from what they normally do (as when Jon calls Ed). Our data indicate that the recording glasses may be more intrusive than a stationary camera, which is a clear disadvantage of this method.

This leads us to RQ2. Our preliminary findings point out three areas where research on motivation and learning will be informed in new ways through data obtainable only by using video recording glasses.

- *Engagement with task.* The video recording glasses cannot directly measure cognitive engagement with task. But they can provide detailed behavioral information on time-on-task and on the specific activities undertaken. The latter includes instructions-reading, personal note-taking, text annotation, movements across the room to consult teachers or peers, and movements out of the room to get further material resources or consult other people. The visual data will be supplemented by what the student and the persons around him/her say. Conversely, the glasses provide information on non-engagement with the task, as in the narrative, and on what students spend their time on instead. Such information would not be available in the same detail with other methods: A stationary video camera will not follow students if they move and will typically not be close enough to record all details. A researcher held video camera cannot be held close enough to the student. Prompted statements interrupt the flow of activity. Observer notes cannot provide as minute and rich details on task activities. In retrospective interviews, students cannot remember information to the same detail as that which the glasses provide.

- *Self-regulation strategies.* The video recording glasses cannot directly measure self-regulation strategies. But detailed behavioral information can provide valuable information on what students actually do to monitor their learning which may supplement subjective student reports on the matter.

- *Catch and hold of interest.* Again, interest is not directly measurable by the video recording glasses since students need not be cognitively focused on what is within sight; they might e.g. be daydreaming instead. Still, the accompanying audio data often supply information on this point. The narrative provides a clear example of how information on catch and hold of interest can be displayed in data: The triggering of Jon's interest in the off-task activity of geoguessing is unambiguously evidenced in the combination of visual data on what he is looking at, the audio data of his repeated questions to the other group and the visual data of his moving over to them. Hold of interest is evidenced during the rest of the film in his continued gaze at the screen and his interaction with the website and the group.

- *Providing a person-in-context perspective.* In situ studies within the field of learning and motivation seek a person-in-context perspective (e.g. Cobb, Stephan, McClain, & Gravemeijer, 2001). The aim is to integrate a focus on the individual with an understanding of the situated interaction in class. Taking 'perspective' literally, this is precisely what the video recording glasses supply. Of course, the literal perspective does not directly convey the individual's perspective, understood as 'understanding and experience'. Still, the behavioral and interactional data provide important information about the first-person view during the course of action in a way not possible with other data collecting methods.

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Acknowledgements

Designing Side-By-Side and In-The-Moment:
On the Participation of Youth in Professional Learning Settings

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Abstract: This study explores the non-normative inclusion of students in teacher professional learning settings and demonstrates the power of designing side-by-side and in-the-moment. In one urban Hill tribe school in Thailand, we find that legitimate participation of students in teachers' professional learning was key to 1) shifting deficit frames of youth to ones of strength, 2) facilitating teachers' re-imagination of classroom participant roles and 3) bringing researchers closer to scaling equitable design for deep learning.

Introduction: Major issues and potential significance

Using a Tutoría Camp at Sahasat school as a case of professional learning with radically different participant structures, we explore how deep engagement with heterogeneity helped shift deficit perspectives of Hill tribe youth at school and power paradigms between teachers and their students. Furthermore, we explore how we designed side-by-side and in-the-moment in a social design experiments (Gutiérrez & Vossoughi, 2010) are important to create emergent activity systems that take hold as counter-hegemonic practices at school. We asked the following questions: (1) How can we design professional learning settings that include student voice so that deficit framings of students can be shifted to ones of strength? (2) What new meaning-making practices do both students and teachers experience when professional learning allows for learning across generations and cultural communities, and (3) How does this alter top-down power paradigms of static roles at school?

Methods: The design and context

In Thailand, the Hill tribe population is constantly framed as being deficient when contrasted to Thai normativity and culture. Often in Hill tribe schools, instead seeing multiple cultural practices within the school as an asset to the construction of a rich learning environment, heterogeneity or "otherness" is often seen as a deviation from the established dominant norm. The goal of our design research was to see how deficit framings of students and power paradigms between teachers and students could be shifted to ones of resiliency and strength when (1) students were legitimate participants in professional learning settings and (2) when we designed connected learning roles to disrupt ideas about who contains and creates knowledge in school through a practice called Tutoría. Originating from México, the Tutoría pedagogy is based in a one-to-one tutoring practice where reflective discourse is used to transform traditional one-way "teacher-learner" roles into bidirectional ones (Rincón-Gallardo & Elmore, 2012). Over the two days, the camp was organized in seven sessions that built upon each other.

Data and analysis

Data was comprised of field note data, student and teacher designed *Temas*, their reflections along with video clips and photos. Design-meeting conversations were also collected and analyzed. This data from went through four stages of coding and analysis. (1) Field note and design team meetings transcribed in Thai and English. (2) Transcripts were then coded in MAXQDA using Grounded Theory Analysis (Charmaz & Belgave, 2002), (3) Memo writing and sharing of data trends using emergent codes. (4) Re-coding of data using codes.

Preliminary findings

Finding 1: Student legitimate participation humanizes learning

One fundamental shift for the teachers at the end of the camp was a move from what the curriculum mandated teachers to do, to fundamentally understanding their students as individual human beings and how they learn.

> Teacher O: My experience is different from yours. I had never seen my students tutor before. One thing I noticed was that they were tutoring in Akha (a Hilltribe language). I told them, you can't use Akha to explain it to each other because tomorrow, students from CVK are coming and you can't use Akha with them! But actually now that I think about it, they actually should speak any language, like Akha.

This except notes a direct rejection of normative labelling of students as academically "strong" or "weak." Furthermore, it marks shift in the normative suppression of Akha but allow students to "speak any language"

instead. What mattered was not the language, but the thought and the deep learning that happens when one engages in dialogue in their language of choice. In this shift from a curriculum-centered framing to a learner-centered frame, she began to see her in more humanizing way.

Finding 2: Connected Learning facilitated teachers' re-imagination of classroom roles

Building upon the shifts in deficit framing of the students at Sahasat, the cyclical culture of learning in the Tutoría camp where dynamic and interchangeable "tutor" and "tutee" roles were constantly in flux problematized normative power paradigms between students and teachers. Students began to see themselves as legitimate actors in the learning network and were looking for ways to expand their practice to other spaces and times.

Student 1:   Everyone can help teaching. Every classroom should be equal.

Student 2:   I feel that I like it because I have taught others and they can teach others later.

Finding 3: Designing side-by-side and in-the-moment is key for equitable design

The values of our design needed to be aligned and congruent to the values of Tutoría itself. Thus, keeping the design space "open" to disruptions from adults and youth was a meta-model of the how the Tutoría network itself was designed to function. As a design team, we had initially participated in the segregation of ages.

Designer 1:   We don't have a Primary 3 students there that's doing Tutoría. That's the problem. Coz those that were teaching that day were much older.

A key feature of the design was that we remained open to the pushing and agency of both teachers and students. Noticing our worries, they started to organize the space of the camp, which led to learning across grade levels in the camp. This became one of the highlights for many teachers and students. With one student saying, "The younger students encourage me to think." Without designing side-by-side and in-the-moment, our Tutoría camp would have continued to deeply reinforce deficit framings and power paradigms between us and the camp participants. As such, in-the-moment noticings and iterations for the design alongside its participants must be a tenant of any equitable learning environment.

Conclusions and implications

The study questions the absence of students in professional learning settings and argue instead that students' legitimate participation in such activities is critical to the sustained development of new teacher practices. The findings from this paper reveal the rich potential for learning when professional learning environments are designed with heterogeneity in mind (Rosebery et al, 2010) where youth, adults, and researchers learn side-by-side (Erickson, 2006). Formal educational institutions often resist change and current efforts in school reform not only fall short of creating truly expansive learning environments, but continue to reproduce inequalities for oppressed peoples. The results of this study shed light on the importance of inclusion and student voice in disrupting deeply-rooted social structures in education systems so as to create an emergent activity system where expansive learning can take hold within a formal school context (Engström & Saninno, 2009).

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Acknowledgments

The AFS Educational Approach in Developing and Assessing Intercultural Competence

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Abstract: The objective of this poster is to discuss a work-in-progress of the "AFS Educational Approach" which is a program designed to help participants on the AFS study abroad program develop their intercultural competence. The AFS Educational Approach views intercultural learning as a process that involves adapting and adjusting to different cultural worldviews. This poster discusses the use of an e-Portfolio in order to evidence the student's intercultural learning experience.

Introduction

The AFS student exchange program involves an individual going to live abroad with a "host family" who hosts them throughout a period of typically 5 to 10 months, while the individual also attends a local school. The students on the program are typically aged between 15 to 17 years old and come from over 60 countries around the world.

The student will have to learn and adjust to a new culture and this process is challenging in many ways (Gudykunst, 1998). Despite being a challenging process, the popularity of exchange programs is growing. Each year, AFS Intercultural Programs sends around 13,000 students a year abroad on exchange programs (AFS, 2016). With the potentially large number of students going abroad on exchange with various organizations each year, there is a growing interest in the area of intercultural learning through mobility, especially in assessing and measuring the effects of such study abroad programs.

The development of intercultural competence involves more than just knowledge about one or more foreign cultures. A person with intercultural competence has the willingness and ability to appropriately and effectively apply the attitude, skills and knowledge gained into their interaction with the people around them. This involves being aware of the cultural differences, similarities and also understanding one's own culture and the foreign culture. Intercultural attitudes such as curiosity and openness to cultural differences will help with this development of intercultural competence. Such skills are not easily taught through traditional, formal pedagogical methods and developing intercultural competence is largely a self-discovery process that happens through explicit, structured reflection about experiences when interacting with people, constructs, etc. outside of one's own culture(s).

The AFS Educational Approach

The AFS Educational Approach is based on sixteen goals and forty-one learning objectives grouped into four categories (personal, interpersonal, cultural and global) that each student on the program works to develop as part of their lifelong learning experience. In order to achieve these goals, a comprehensive curriculum including a monthly learning reflection program was designed to help participants discover and cultivate skills that are critical in developing their intercultural competence. An optional e-Portfolio is being piloted to help evidence the students' intercultural development overall and against seven specific goals.

Monthly learning reflections to promote critical reflection

Learning can be defined as the process of making meaning or revised interpretation of an experience. This forms the foundation for transformative learning (Mezirow, 1997) where learning is grounded in human communication and circumscribed by a frame of reference. The frame of reference (e.g., cultural beliefs, stereotypes, moral norms) are the individual's point of view which influences their thinking, beliefs and action. During the intercultural learning process, the individual's existing frame of reference, which is grounded to their home culture is challenged and alternative frame of reference may need to be developed or paradigmatic shifts need to take place.

In order to transform our frame of reference, Mezirow (1997) argues that critical reflection needs to take place. Using this as a framework, the monthly learning reflection program was designed to help students reflect on their experiences in their host community. The structured reflection activities will be facilitated by a "contact person" who is assigned to the student as part of their AFS Student Learning Journey. This contact person is a trained volunteer who is based in the same local community as the student and will act as a cultural informant as

well as a nonformal learning facilitator. The monthly learning reflection activities are designed to challenge the student's frame of reference with the contact person playing a critical role in both prompting and providing cultural insights into the experience.

e-Portfolio as a repository of intercultural learning

Additionally as part of the AFS Student Learning Journey, participants can create an e-Portfolio that will serve as a repository of their experience. The e-Portfolio is a collection of artefacts that students, after creating a learning agreement, gather during their time abroad to demonstrate their intercultural competence development and reflect on their learning. It will serve as a learning tool for participants to monitor their own learning and evidence of their intercultural learning experience for future college admission or employment opportunities. One advantage of using e-Portfolios is the monitoring process that shifts from being course-driven to being student-centered.

Among the artefacts created are those building on the monthly learning reflection activities such as reflective journal entries, photo and video journaling. Video journaling is a powerful tool for intercultural learning (Goulah, 2007) as it provides evidence especially in language development and non-verbal communication skills. For example, students are able to reflect on their language development by reviewing artefacts created at different points in time. In addition to self-created artefacts, students are provided with additional measurement tools to track their development such as the Intercultural Effectiveness Scale (IES) (Kozai Group, 2015), a modified version of the ILR Language Assessment (Interagency Language Roundtable, 2015), and measurement across seven AFS goals and related learning objectives. Additionally, trained "assessors" will provide students feedback on observed progress in pre-identified goal areas using an assessment rubric developed based on AFS Educational Objectives and AAC&U's VALUE Rubric (AAC&U, 2015).

Summary

In this poster, we aim to discuss the AFS Educational Approach and how it encourages students to be active participants in their own learning through learning agreements, monthly learning reflections and e-Portfolios to evidence their experience. Each student is likely to go through a unique learning process during his or her time abroad. The AFS Educational Approach aims to provide learners with the tools to make the experience more meaningful and one that can be readily expressed to others in meaningful terms.

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Improving Self-Detection of Confusion:
Is Metacognitive Monitoring a Key?

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Abstract: Self-reporting of confusion is often seen as a quite unreliable way to measure this cognitive affective state. Testing the link between metacognition and confusion detection, in this study we have investigated two prospective interventions to improve self-reporting of confusion along with improving students metacognitive monitoring. Prospective implications for confusion research, research on metacognition and mathematics education are discussed.

Major issues addressed

Confusion became a recent focus of educational research as a natural phenomenon occurring while learning about complex science topics and promoting deeper understanding and elaborated processing of new information (D'Mello & Graesser, 2014). However, a reliable detection of confusion is still a challenging question for researchers: complex computational models configured to identify learners confusion based on a powerful stream of learning analytics are still being developed by learning sciences researchers while self-reported measures of confusion are often considered unreliable and lacking precision (D'Mello & Graesser, 2014). Proposed models of cognitive-affective states (e.g. D'Mello, Lehman, Pekrun & Graesser, 2014) suggest learners are transitioning into the state of cognitive disequilibrium and experience confusion after an impasse is detected. Meanwhile, several factors are argued to moderate successful impasse detection, metacognition, being one of them (see Pachman, Arguel, & Lockyer, 2015). These authors posit that poor metacognitive monitoring leads to reduced chances to detect an impasse, experience confusion and, ultimately, to missed learning opportunities. In this study we attempt to use an intervention traditionally used in metacognition research, such as worked examples (Baars, van Gog, de Bruin et al., 2014), in order not only to improve metacognitive monitoring but also self-reporting of confusion. Thus, we are testing the link between metacognition and impasse detection previously argued in Pachman, Arguel and Lockyer (2015). We also test a possibility of improving metacognitive monitoring and self-reporting of confusion with a difficult prior task (Advanced Ravens matrices items). This second method is mostly used in mathematics education to improve learners performance on conventional and insight problems (Attridge & Inglis, 2015). Insight problems in this context are defined as problems that require a learner to shift his or her perspective and view the problem in a novel way in order to achieve the solution. Insight problems serve as a natural source of confusion and have been used in confusion research previously (Pachman, et al., 2015). We also use them in a present study. To sum up, in this study, we aimed to answer the following research questions:

1. Do pre-training including worked example and pre-training including a difficult task promote more accurate metacognitive monitoring?
2. Will the changes in the level of self-reported confusion correlate with the changes in metacognitive monitoring measures?
3. Will either type of the pre-training result in a better practice and a final test performance?

Significance of the study

In addition to confirming the existence of the link between metacognition and impasse detection as it has recently been argued in the literature, this study also tests the inclusion of a difficult task (items from Advanced Ravens matrices) as a mean of improving metacognitive monitoring. A traditional method to improve metacognitive monitoring, such as worked examples followed by a practice problem, helps students comprehend a solution procedure, thus, students monitoring statement are based on this comprehension rather than literal memory /surface features of the problem (Baars, van Gog, de Bruin et al., 2014). Advanced Ravens matrices items presented before the task are argued to promote elaborated effortful processing of the information and inhibit a shallow processing (Attridge & Inglis, 2015). In this sense they can4 be argued to help students focus on comprehension of the problem structure rather than surface features the same way worked examples do and potentially contribute to improving an accuracy of metacognitive monitoring.

Finally, a partial replication of Attridge and Inglis (2015) study and an inclusion of worked examples are aimed at exploring methods promoting deep elaborated processing of the information and inhibiting a shallow processing, and has a significance for mathematics education research

Theoretical and methodological approach

In this study we treat metacognitive monitoring as an integral part of the self-regulated learning, i.e., goal setting, monitoring progress toward these goals, self-evaluating (Winne & Hadwin, 1998). An accuracy of metacognitive monitoring is routinely measured by interrelation of Judgments of Learning, JOLs (learners predictions about their future performance based on the materials learnt, problems solved) and the subsequent performance Baars et al. (2014). We have used an experimental approach with 3 conditions (Table 1). Please note, the greyed out part is sequential, for example, each control group problem is preceded by filler task, followed by confusion rating, then, followed by the other filler and a JOL.

Table 1: Experimental design

Control group	Experimental 1	Experimental 2
Pre-test (numeracy)		
Filler task (equalizing time)	Pre-training 6 Advanced Ravens items	Pre-training worked examples (for 6 insight problems)
6 insight problems		
Self-ratings of confusion (Likert scale)		
Filler task (delayed JOLs)		
Metacognitive monitoring ratings (JOLs)		
Final test (6 similar insight problems)		

This is a study in progress, and we are currently in the process of analysing data. In this study, we will have about 60-75 participants, university students, recruited via online and on-campus advertisement and randomly assigned to one of three conditions. All the materials are computer-based, delivered via secure sequence of Qualtrics with JavaScript snippets. The data will be transferred to SPSS and analysed statistically. Measures of bias and standard deviation are calculated similarly to Baars et al. (2014).

Predicted results and implications

We hypothesized that experimental groups will exhibit improved metacognitive monitoring (their bias and absolute deviation will be smaller) in comparison with a control group. If it is true, then giving learners complex tasks, like Advanced Ravens matrices, before insight problems and using worked examples are equally effective for improving the accuracy of their metacognitive monitoring. Also, we believe that consistent changes in confusion ratings will correlate with consistent changes in metacognitive monitoring measures. If it is true, it will confirm the importance of metacognition for impasse detection and, ultimately, for seizing a productive potential of cognitive disequilibrium. Finally, we expect to replicate the results of Attridge and Inglis (2015) in regard to introducing Advanced Ravens matrices as a difficult task helping students to inhibit shallow type of processing and promoting deep elaborated processing which will improve their problem solving. We also hope that worked examples being a known method to improve conventional problem solving could be effective with insight problems. The study will have wide implications for confusion and metacognition research, as well as for mathematics education research.

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Acknowledgments

How Teachers Can Boost Conceptual Understanding in Physics Classes

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Abstract: We enriched the curriculum of mechanics with instructional elements that had been proven to foster conceptual change (e.g., self-explanation prompts and metacognitive questions). Four physics teachers in charge of two parallel classes each implemented the enriched curriculum in one of their classes (CogAct classes) while they taught the other class as always. The sample included 172 students from higher secondary school. CogAct classes outperformed conventional classes in terms of conceptual understanding and quantitative problem solving.

Introduction

Difficulties in learning physics have been extensively demonstrated in the field of mechanics, where students enter classes with various naïve beliefs and misconceptions. Learning research has developed and evaluated instructional elements that encourage focused processing of the conceptual knowledge to be learnt. These cognitively activating elements include among others: instructing students to generate self-explanations (Berthold & Renkl, 2010), presenting learners with contrasting cases that help highlighting the underlying conceptual structures (Schwartz, Chase, Oppezzo, & Chin, 2011), and metacognitive questioning (Mevarech & Fridkin, 2006). It is, however, far from certain that instructional elements proven successful in controlled experimental studies will find their way into the classroom. At the MINT-learning center of our university (http://www.educ.ethz.ch/mint/index_EN), we enrich traditional curricula with cognitively activating elements that have proven to foster conceptual understanding. In the following, we present a study that compares an enriched curriculum targeting Newtonian mechanics (the CogAct curriculum) with conventional instruction. Across three measurement points (pre, post, and follow-up), we assessed the students' conceptual understanding and quantitative problem solving performance to evaluate the effectiveness of the new curriculum.

Methods

The Cognitively Activating (CogAct) curriculum

The MINT-learning center developed a curriculum on introductory mechanics composed of 16 lessons that focus on concepts such as inertia, weight and mass, as well as acceleration and force. The lessons were enriched with the cognitively activating instructional elements summarized above. In general, the curriculum is organized in terms of questions that are stimulated to come up during the lessons and answered later on. The sequence of the topics is chosen in a way that each topic follows naturally from the preceding topic to help the students build coherent and solid knowledge structures that make sense to them and therefore facilitate active knowledge construction. Observable real-world applications that connect to existing knowledge are intended to raise motivation and broaden the understanding of the underlying concepts. Importantly, the CogAct curriculum focusses on the observation and description of phenomena, while the formalization is to happen along the way. Accordingly, instructional time is spent predominantly on developing a conceptual understanding of mechanics contents, while students are expected to learn the use of formula in passing. Therefore, as compared to conventional instruction, considerably less time is devoted to practicing quantitative problem solving.

Student sample and design

The sample consisted of 8 classes comprising 172 Swiss students (92 females; age 15-16 years) from the advanced track of higher secondary school (Gymnasium). Four classes, i.e., 87 students (48 females), received the CogAct curriculum. Four volunteering physics teachers in charge of two parallel classes implemented the CogAct curriculum in one of their classes while they taught the other class as always. All of the four teachers underwent a two-day training dealing with the CogAct curriculum. We made sure that the same topics concerning basic Newtonian mechanics were covered during the same time period in both the CogAct classes and the classes that were taught conventionally.

Measures

Conceptual understanding was assessed with a Rasch-scaled multiple choice test that captures conceptual understanding of basic mechanics presented as pre-, post-, and follow-up test 3 months after the intervention. The problem contexts implemented in the test were explicitly not discussed during instruction, neither in the CogAct curriculum nor in the classes that were taught as always. All items of the test required the students to apply their conceptual understanding to new situations. The test hence assessed deep conceptual knowledge that can be transferred to superficially new problem situations. We further developed a quantitative problem solving test that required the students to read graphs, apply formulae, and calculate. It hence closely resembled standard physics examinations. This test was applied as posttest and follow-up test. In addition, Raven's advanced progressive matrices were administered in the pretest session to obtain an indicator of the students' intelligence.

Results

The conceptual understanding and quantitative problem solving post and follow-up scores were regressed on condition (conventional instruction vs. CogAct curriculum) and a number of control variables (age, gender, specialization on non-STEM vs. STEM subjects, intelligence, and prior conceptual understanding). The analyses revealed a significant superiority of the CogAct curriculum regarding the students' conceptual understanding at the posttest ($\beta = 0.19$, $SE = 0.06$, $p < .01$) and at the follow-up test ($\beta = 0.13$, $SE = 0.07$, $p < .05$). The CogAct curriculum also led to a significantly higher quantitative problem solving performance at the posttest ($\beta = 0.14$, $SE = 0.07$, $p < .05$), while there was no difference between CogAct and conventional instruction at the follow-up test. Females from the highest quartile of the intelligence test particularly profited from the CogAct curriculum (see Figure 1, including 95%-confidence intervals). They outperformed the highly intelligent females in the conventional instruction classes on the conceptual understanding posttest and the quantitative problem solving posttest. While highly intelligent males outperformed equally intelligent females in the conventional instruction classes, this was no longer true in the CogAct classes. The follow-up results point in the same direction.
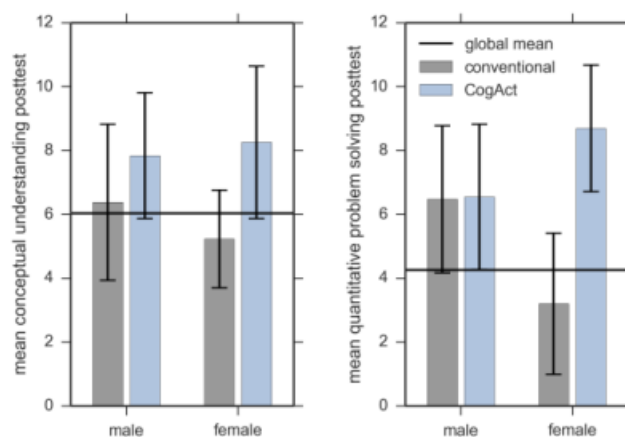
Figure 1. Mean posttest achievement of students with intelligence above the 75th percentile.

Conclusions

We could confirm that enriching physics instruction with instructional elements that foster deep processing of conceptual knowledge improves achievement in terms of conceptual understanding. The CogAct classes outperformed the conventional instruction classes also on the quantitative problem solving posttest, although, in conventional instruction, teachers spent more time on practicing quantitative problem solving. With moderate effort, regular physics teachers can learn how to foster conceptual understanding and mitigate the gender gap.

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How to Support Senior Citizens' Media Literacies: A Review of Existing Research Literature

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Abstract: Media-related competences are crucial in present-day societies. However, people aged 65+ generally use the internet less than younger age groups. Therefore, senior citizens are at risk for being excluded from participation in society. In this poster, we review research literature on senior citizens' media literacies in search of answers to the following questions: What is the level of senior citizens' media literacies? What kind of pedagogical approaches are suitable for supporting senior citizens' media literacies?

Introduction

Information and communication technology (ICT) and media-related competences are of the utmost importance for three key purposes: (a) democracy, participation, and active citizenship, (b) the knowledge economy, competitiveness, and choice, and (c) lifelong learning, cultural expression, and personal fulfilment (Livingstone, Van Couvering, & Thumim, 2005). However, people aged 65+ generally use the internet less, and for less versatile purposes than younger age groups (e.g., Ofcom, 2015; Hakkarainen, 2012; Hakkarainen & Hyvönen, 2010), and are, therefore, at risk of being excluded from present-day and future digital services. Media literacy and digital competence-related research has focused mainly on children and adolescents, and not adequately on older people. In our poster, we respond to this topical challenge by reviewing research literature on senior citizens' media literacies. From the existing research literature, we will present answers to the following questions: *What is the level of senior citizens' media literacies? What kind of pedagogical approaches are suitable for supporting senior citizens' media literacies?*

Previous studies on senior citizens' media literacies

Senior citizens' *media literacies* can be defined and assessed using various media literacy definitions and frameworks (e.g., Ofcom, 2015; Hobbs, 2010), as well as related concepts such as *digital competence*, *digital skills*, and *media competence*. Digital competence refers to "the confident, critical and creative use of ICT to achieve goals related to work, employability, learning, leisure, inclusion, and/or or participation in society" (Punie, 2013, p. 2), whereas according to, for example, Ofcom (2015, p.19), media literacy is "the ability to access, understand and create communications in a variety of contexts." In comparison to the concept of media literacy, "digital competence" has been assessed as being narrower and more instrumental in its focus (see, e.g., Gutiérrez & Tyner, 2012).

Albeit scarce, the existing research on senior citizens' media literacy indicates that there is a need to support their skills and competences. A recent report by Ofcom (2015) on media use (TV, radio, mobile phones, games, the internet), attitudes, and understanding among UK adults aged 16+ showed that both newer and narrow users of the internet were predominantly aged 65+. Narrow users' self-reported confidence in using the internet was lower than that of younger age groups. Furthermore, the study indicated that their understanding about how search engines operate was more restricted, as well as their competence in critically assessing the accuracy of search engine results. Finally, the awareness and use of security measures was lower than that of younger age groups who used the internet more broadly.

How do senior citizens develop media literacies?

Vroman et al. (2015) have explored the use of ICT by North Americans aged 65+. The results reveal that the most salient factors that explain senior citizens' motivation to learn and use ICT are their *personal interests and needs*. Accordingly, Vroman and colleagues suggest a *person-focused approach*, in other words, when designing learning for elderly, the design should always be based on their individual, subjective interests and needs, which differ partly from those of younger generations.

Previous research indicates that senior citizens' *self-efficacy as technology user* is positively related to their development of media literacy (Livinstone et al., 2005; Vroman et al., 2015). A case realized through collaborative and playful learning practices and performed in rural Finland, corroborates this finding (Hyvönen, Romero, Hakkarainen, & Impiö, 2013). The participants were provided with tablet computers that none of them had used before. To start with, the participants' assessment of their competence was modest and most of them reported the emotions of fear and disbelief related to their abilities to learn. In other words, their *self-efficacy* was

low. Despite fear and disbelief experienced in the beginning of the intervention, the participants made connections between the tablet and their prior skills and hobbies, thereby taking their competences to a new level. Collaborative learning and "a license" to be creative and playful was key to learning. At the end of the study, the participants identified themselves as competent learners (Hyvönen et al., 2013).

The meaning of *social support networks* is crucial for senior citizens' learning of media literacy. Pedagogical interventions that build on peer support and collaborative and creative problem solving have attained positive results (e.g., Hyvönen et al., 2013; see also Romero, Hyvönen, & Barberà, 2012). Research has also indicated that older people willingly learn to use the internet under the guidance of their *friends* and *family* members (Livingstone et al., 2005; Rasi & Kilpeläinen, 2015). For example, a study focusing on digital competences of older people living in small, remote rural villages showed that older people's spouses, children, grandchildren, and fellow villagers had a key role to play in their use of media and the development of media literacy (Rasi & Kilpeläinen, 2015).

Finally, we would like to emphasize three factors that support senior citizens' development of media literacies. First, research dealing with older people's internet engagement recommends promoting *a metacognitive approach to learning* (Hill, Beynon-Davies, & Williams, 2008). Second, research pertaining to older people's learning of media and ICT competencies has highlighted the importance of making sure that the participants *understand the technological concepts* being used during the instruction (Xie, Watkins, Golbeck, & Huang, 2012). Third, within the field of intergenerational studies, encouraging results have been attained from technology-oriented *intergenerational learning programs*, in which youth with technology expertise have acted as technology tutors or teachers of the older people (see Sánchez, Kapland, & Bradley, 2015).

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Learning With Peers: Problem Solving Through Pair Collaboration

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Abstract: This paper examines how two young-adult novices engage in problem-solving tasks through collaboration. The research focusses on the participants' observable behaviours such as language, expressions, gestures, and social contexts. While research has targeted problem solving in tutoring and group learning, this work addresses the interactions that operate within the dyad. This study can extend conversations within the situated learning field in how learning processes are enacted and maintained between peers.

Introduction

My research investigates the ways that coupled participants engage in problem-solving through observable behaviour, e.g. gestures, facial expression, turn taking, body positioning, and speech. While there is significant research of interactional analysis in small groups and online communities, there has been little focus on face-to-face interactions that take place between peers, (Bales, 1950; Richard Hartley, 1966). My work will centre in such a context to begin to fill in the knowledge gaps of practices within a dyad's communication and action patterns (Golder, Wilkinson & Huberman, 2007). In focusing on how pairs learn, in which context it occurs, and what is learned, this study offers one of the ideal contexts for observing how social contexts structure situations so that knowledge is accessible to all learners, (Lave & Wenger, 1991).

To meet this need, an innovated Learning Interaction lab at OISE/University of Toronto was designed to capture interactions and speech in various ways using video and microphones set up throughout the room. In the proposed pilot study, we will study two peers collaborating on a problem solving task and observe the interactions that take place, specifically focusing on observable behaviours. The task itself had one correct answer, simplifying how success is defined and the learning outcomes.

Studies of groups and problem-solving abound. Notable contributions focus on instruction and tasks within the classroom, such as the zone of proximal development (ZPD) which typically involves one individual who is more of an expert in the task, (Vygotsky, 1978). These studies are important but often focus on curriculum and pedagogy rather than theorizing about learning processes. They also tend to not centre attention on the collaborative process of learning and how it unfolds, nor do they focus on the people position themselves and others outside of classroom, (Holland, 2001). They tend to lean on teachers and traditional ideas of cognition, providing a framework for approaches to student success, who is then assumed to increase their achievement and improve their academic skills (Zuengler & Miller, 2006). Such an approach misses the dynamics of learning in formal and informal settings and communication of one's thoughts process into action to their partners.

In contrast, my proposed research will observe the learning processes involved a problem solving task in the learning lab and examine how paired young adults participate, handle conflicts, and interact (Pelled, Eisenhardt &Xin, 1999; Xie, Swift, Cairns & Cairns, 2002). The results of my research will not only inform education and educators, but find application in broader contexts such as professionals or novices attempting a task, and policymakers. My work also attempts to address power dynamics and positional identities, Like many community learning research, my view is based on a view of learning that goes beyond the mind of single individual, where learning is a social act where meaning is co-constructed and negotiated and is continually revised, maintained and transformed through interaction, (Lave & Wenger, 1991; Brand & Opwgi, 2007). I will analyze the ways that pairs of people participate – individually and collectively – and therefore the social setting in knowledge acquisition, (Jordan & Henderson, 1995). These micro-level interactions constitute the process of learning and how it is mobilized, as individuals learn through and from each other's speech and interactions.

Proposed methods

Using video recordings, I will trace the learning process as two participants engage in a problem solving task with one task with one "correct" answer. As an observer, I will record video from an observation room next to the learning lab. Using video will trace how the individuals talk about the problem, use artifacts, and position themselves and their partner, and identify any possible shifts in participants' participation (Cole, 1996; Radford, 2000; Mondada, 2007). Video also allows me to see how knowledge is constructed, framed and enacted. The choices made can be indicative of the pair's joint attention and shared consciousness and gives insights into how

pairs approach problem-solving. I will focus on observable behaviours to interrogate how they make meaning and understand collaboration.

5 pairs of individuals will be selected based on their response to an open call for participants in a pilot study at OISE/University of Toronto. I will use the state-of-the-art Learning Interaction Lab at the university and StudioCode, a cutting-edge analytical software to combine interaction analysis and discourse in order to deepen understandings of how people learn and co-construct meaning. Video provides unique affordance that are critical to my work, where I use sociocultural theories to understand learning as social and produced through interactions. Video will allow me to see that happening in real time and analyze interactions in full detail, and also allow for repeated viewings, (Jordan & Henderson, 1995; Erickson, 2006). I will supplement the video data with semi-structured interviews that will take place immediately after completion of the task. The interview will last 60-75 and ask participants to review the video, and describe and understand specific interactions.

Analysis

Video data will be imported into and organized through the qualitative data analysis software, StudioCode. The constant comparative method will be used for combing through and coding this data. Initially, the research members and I will view the video and flag specific interactions that are "interesting" and linked to knowledge construction and problem solving. Then we will re-watch the videos respectively, and continue reviewing the data, chunking the instances into emergent themes related to learning processes. Finally, we will compare our analyses and examine our codes together through multiple revisions.

Implications

This pilot study will shed light on how peers learn and interact within problem solving situations – the social settings of knowledge acquisition - an academic area that has not been sufficiently researched. It will be useful for educators, policymakers, and professionals to consider learning in context. Furthermore, this research addresses how practices and identities are enacted, maintained, and shaped.

I have over three years of experience in the methodology of interactional analysis using video and the StudioCode Software. I am part of a team developing new multi-camera methods for video data collection analysis for the *Developing Analytic Methods for Video Data* project. In the department of Curriculum, Teaching, and Learning, I work under the supervision of Dr. Indigo Esmonde and Dr. Robert Simon, who brings expertise in critical sociocultural theory, video-based data analysis, sociology of learning, community-based research, and practitioner inquiry. My expertise, skills, and committee enabled me to succinctly analyze the video data and approach my research goals by deepening understandings of learning in pairs.

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Sequencing Physical Representations With Human Tutors and Virtual Representations With a Computer Tutor in Chemistry

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Abstract: STEM instruction uses physical and virtual representations, which have complementary effects on learning. We present an observational study in which novice students worked collaboratively on chemical bonding. Students were assigned to different orders of physical or virtual representations. A combination of quantitative and qualitative analyses suggests that students engaged in more productive problem-solving strategies if they started with physical representations. They maintained these strategies when switching to virtual representations, which afforded more efficient problem solving.

Introduction

In educational contexts, we face a *representation dilemma* (Dreher & Kuntze, 2014): we ask students to use visual representations that they have never seen before to make sense of content that they have never heard of. Therefore, students need *representational competencies*: knowledge and skills about how to interpret visual representations and how to use them to use them to solve problems (Ainsworth, 2006). Different representation modes have complementary effects on students' learning (de Jong, Linn, & Zacharia, 2013). Physical representations allow for tangible interactions (Figure 1, top). Virtual representations are visual representations that students manipulate via mouse or text input (Figure 1, bottom). When combining these representation modes, the order in which they are provided may matter: there is evidence that students show higher learning gains if they work with physical followed by virtual representations (Smith & Puntambekar, 2010), but there is also evidence that students show higher learning gains if they work with virtual followed by physical representations (Jaakkola & Nurmi, 2008). Based on these contradictory results, it has been proposed that it is not the order that matters, but the affordances the order has for the target concept (Olympiou & Zacharia, 2012).

Yet, we do not yet have a good understanding of how the choice of representation mode and order affects novice students' learning of novel concepts with novel representations. In realistic educational contexts, this question is of practical relevance when teachers have to decide whether to provide computer-based activities with virtual representations or human-led activities with physical representations.
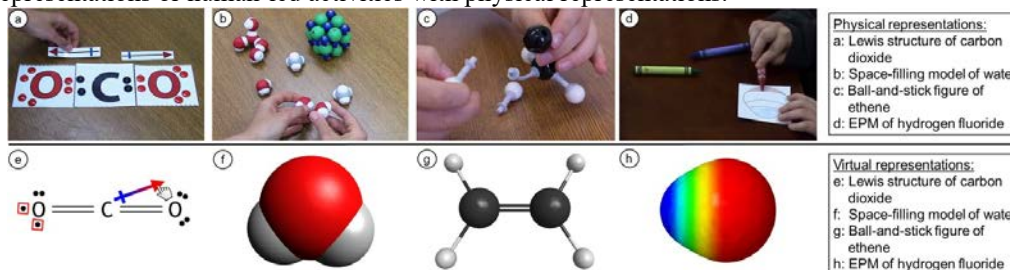
Figure 1. Physical representations (top) and virtual representations (bottom) of chemical molecules.

Methods

We conducted an observational study with twelve students as part of a high-school chemistry workshop. The workshop involved three 3h-long sessions, spread over four weeks. Students had never worked with the visual representations and had no prior knowledge about the target concepts. Students worked collaboratively in dyads that were randomly assigned to physical-then-virtual or virtual-then-physical orders.

During the workshop, students worked on problem-solving tasks introducing them to chemical bonding. When working with *physical representations*, students received a worksheet with several that asking them to construct a physical representation of a molecule, to answer questions about target concepts and about how the representation depicts these concepts. A human tutor provided feedback and assistance the problems. *Virtual representations* were integrated in a computer tutor: Chem Tutor (Rau, 2015), which provided hints and error feedback. Students manipulated the virtual representations to solve problems about chemical bonding. Chem Tutor asked students to explain target concepts and about how the representations depict these concepts.

Students took pre- and posttest. Dyad discourse was transcribed and coded for strategies of problem-solving and reasoning about representations and concepts. Inter-rater reliability was high with kappa = .77.

Results

First, we investigated whether physical and virtual representations have different affordances for problem-solving reasoning strategies. We compared the frequency of codes describing these strategies. We found that when working physical representations, students more often negotiated their answers and planned representations, and engaged in less guessing. Furthermore, students made more connections to representations and concepts. When working with virtual representations, students solved problems more efficiently.

Second, we investigated whether the order of physical and virtual representations has different affordances. We compared the frequency of codes between representation mode orders. The comparison showed that codes that occurred more frequently for physical-then-virtual than for virtual-then-physical orders also occurred more frequently when students worked with physical representations. Thus, it seems that students maintained strategies afforded by their first representation mode when switching to a new representation mode.

Third, we investigated how problem-solving and reasoning strategies related to students' learning success. We compared the frequency of codes between successful dyads with pre-posttest learning gains to unsuccessful dyads without learning gains. We found that codes that occurred frequently in successful dyads occurred more frequently with physical than with virtual representations. They also occurred more frequently with physical-then-virtual than in virtual-then-physical orders. By contrast, codes that occurred more frequently in unsuccessful dyads also occurred more frequently with virtual than with physical representations.

Finally, we used qualitative analyses to gain further insights into how problem-solving and reasoning might relate to learning success. We examined one successful and one unsuccessful dyad. The successful dyad negotiated their answers more often when working with physical representations. These strategies appeared to yield deeper reasoning about representations and concepts. The dyad maintained these strategies when working with virtual representations. By contrast, the unsuccessful dyad often tried to guess answers while working with virtual representations. These strategies seemed to result in more superficial reasoning. They maintained these strategies while working with physical representations and provided incoherent reasoning when making connections to concepts and representations.

Discussion

We investigated affordances of representation mode and order from the perspective of the *representation dilemma* by focusing on students who learned about new concepts with new visual representations. Our findings suggest that physical representations embedded in human tutoring afford problem-solving conducive to reasoning about how visual representations depict abstract concepts. Students seemed to maintain these strategies when switching to virtual representations embedded in a computer tutor, which seemed to afford more efficient problem solving. Because our study is limited due to its small and observational nature, we cannot make causal claims about the effectiveness of representation modes or order. Yet, our findings yield a new testable hypothesis: that novice students may be most successful if a human tutor uses physical representations to introduce novel concepts and then transition to virtual representations embedded in a computer tutor.

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Acknowledgments

From Belief Mode to Design Mode: Report on a Chinese 6th Graders' Interdiscipline on Traffic Control

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Abstract: In Nanjing(P.R.China), a group of 26 sixth grade students from Baiyunyuan elementary school participated in this project. For duration of one school semester, 2 stages of Knowledge Building emerged, in phase I students explored the traffic reality, researched basic traffic issue and its impact, proposed new traffic control, and in phase II, students changed to focus on a big idea of designing future vehicle. Their learning has changed from belief mode to design mode in phase II.

Introduction

Knowledge building (KB) starts with students' ideas from real life and then work out its way by engaging all students in soliciting ideas, discussing issues and developing artifacts(Scardamalia, M., & Bereiter, C. 2003). Knowledge forum (KF, http://kforumhost.motion.com) is the environment where students can post ideas and notes, respond, and track discussion topics all being done via the web. Ideas will be recorded and made available on the web.This paper summarized our experience working with the 6th graders, applying KB under KF in interdiscipline of traffic control, how they picked up the basic traffic knowledge, and how they moved to design future traffic vehicles as the deep knowledge construction. We hope this paper will encourage more thinking and planning to implement KB and apply them to regular school curriculum in a Chinese school.

Methods

The method is design-based research, the purpose is to find out how to deepen the using of KB and KF in a Chinese classroom where is exam-centered? how to design teaching and learning? what will Interdiscipline curriculum emerged, how can an instructor improve students learning from belief mode to design mode?

Student participation

A total of 26 sixth grade students and a teacher participated in this study.

Analysis

The data collection throughout the study includes notes during students' participation, interviews, student paper and discussions in KB. Most of the data collection was from the KF.

Findings

In phase I, the instructor encouraged students to state traffic conditions around the school, to describe behaviors from bicyclists, drivers, and pedestrians, and to raise questions and ideas in KF. Students showed big interesting in the beginning, however,3-4 weeks later, the instructor found that students have exhausted their theories, couldn't ask any more meaningful questions and even didn't have any questions at all.

Then, students were recommended to go to street again with their research partner and try to find real traffic problems and use their old theories to explain it, try to improve their theories. In phase II, students filter out random and unrelated thoughts and form related high quality cohesive theory. They decided to focus on a big idea "traffic design " reach an agreement to improve traffic flow.They first designed from the KF discussion including "concept platform", " concept car "that sails on sea, houses that float in the air" and so on. They then constructed from group discussion after sharing design, criticizing each other's work and evaluating design.

Students contribution: In-width analysis on knowledge building

On average, Phase I shows only 2 postings in KF, by the time they participated in Phase II, the average postings had increased to 15. The total number of postings during Phase II is 244. Follow ups from Phase I increased to 26. These statistics indicated the extensiveness of their participation has increased. Interesting results are that students during Phase II has much more to say in their own words, and are more likely to propose something. The Contribution tool from the KF tracks how many hits students clicked on "My theory", "My research method" or "My research finding". Students mentioned in their postings, words such as "I Guess", "I think", "Results from my inquiry", "Notes from my interview".

Formative knowledge: In-depth analysis on knowledge building

Analyses over essay questions based on scale from Carol Chan, Eddy Lee and Jan Van Aalst (2001). During Phase I 61% of these questions were about the basic definition; in Phase II, the percentage decreased to 22%. During Phase II, inquiry and interpretation went up to a combined 70% from a mere 15% in Phase I. The transition is obvious from simple definition type of questions to issue itself and interpretation. Students asked how traffic lights are designed, to why pedestrians cross red lights more than cars. Interpretation went up from 2% during Phase I to 33% in Phase II.

Team interaction: Path analysis on knowledge building

KF provides social network analytic tool, and shows that reading and discussion increased drastically from Phase I when students are learning the traffic basics, to Phase II when students are tackling the design issue. Density on reading increased to 51.26% from 4.13%, discussion has increased to 20.22%. As time progressed, students were more interested in others perspectives. They were more likely to question each other, refine and improve their traffic design. The path to knowledge building has gone through each student, through team, and through the entire class.

Student self-evaluation: Attitude analysis on knowledge building

Student self-evaluation shows that students demonstrated higher scores in knowledge readiness, social interaction, and fulfilling task during Phase II than Phase I. The difference in accepting perspective, refine perspective, knowledge in community, knowledge in workspace is even larger between the two phases. Students appeared to be more accepting others, focusing more on others' perspectives, interacting more with peers, caring more about team progress, collaborating more with other team members, and are overall more interested in improving team process.

Conclusions and implications

This paper summarized our research working with 26 6th grade students from Nanjing Beiyunyuan Elementary school in spring 2014. Our findings supported the hypothesis that KB based on KF improves the quality of student learning, and enhances their understanding of subject matters of interdicipline. From phase I to pahse II, the participation expressed learning changed from belief mode to design mode.The reason behind the changes are 1) student experienced on their own, from what they observed, their interest level increased. 2) Increased level of research, students can use questionnaire, interview, or observation, collect first-hand data, including journals, videos, audios, and pictures. Their answers are more creative. 3) Interaction between instructors and students has increased, students had more time to speak to their instructors, and their analysis on issues was more involved.

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Acknowledgments

Organizing to Cultivate Personal Relevance, Science Literacy, and Equity Through Data Journalism

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Abstract: Supporting students' STEM literacy entails creating opportunities for students to contextualize science in their own lives and cultivate STEM identities. We use an interpretive case study framework to examine how we supported, reframed, and challenged students' STEM identities during a two-week teen summer camp on data journalism. We argue that designing for learning requires openness to individual identity trajectories and flexibility of outcomes.

Introduction

The STEM Literacy through Infographics (SLI) program investigates how creating science news infographics through data journalism supports students contextualizing science in their lives and fosters the development of STEM identities. We show *how participation in SLI supported, reframed, and challenged students' STEM identities during a two-week summer camp on data journalism for teens*. Drawing on interpretive case studies, we analyze the experience of three different students to give us greater insight into how their learning experiences were organized and the decisions we made to support, or not, salient aspects of their identities. By articulating these decisions, we reveal our priorities regarding student learning outcomes as well as situate our work within the broader research on learning in STEM. We focus on decisions designers of learning experiences should be mindful of when structuring new learning opportunities which have potential to support, hinder, or lead to alternative entries into STEM futures.

Theoretical framework and methods

We take a sociocultural perspective on learning and identity development drawing on communities of practice (Lave & Wenger, 1991), and trajectories of identification (e.g., Polman & Miller, 2010). We view learning as socially organized, dialogic, and relying on cultural tools to support identification and development. In this instance, infographics play an important role in organizing activity, serving as *boundary objects* (Star, 2010) by connecting students to broader communities by leveraging students' interests and serving as vehicles of participation.

Our research method is interpretive case study as it is way of describing, understanding, and explaining a phenomenon in a naturalistic setting (Yin, 2009). We examine three cases of teens selecting a personal interest, how they connected this interest to scientific and societal contexts through a process of researching data and information, and then iteratively representing the data and information visually. The data sources for these case studies include observations of camp activities recorded in field notes, informal interviews with students during the activities, content logs generated from video recordings of the activities, and artifacts created by participants including the initial and final drafts of their infographics. In what follows, we present a case study of a student whom by most measures was successful in our summer camp, but on further inspection we have much to learn from her. In our poster, we develop two other student case narratives, which challenge the assumptions of our project goals.

Case study: Amber

Amber, entering her junior year, came in with a strong STEM identity, displaying evidence not only that this is how she sees herself, but also, that this is how others see her. She often attended science summer camps, said her favorite superpower would be the ability to change statistics, and she raised her hand when asked if she identified with each category: math, science, and writing. Amber stated multiple times during the camp that she planned to go into engineering. Amber also displayed a critical disposition to social realities. For example, during an eye-tracking activity she discussed the usefulness of the technology saying it had the potential to reveal differences between how different groups, such as different ages or genders, might take in information. Amber's initial idea for an infographic was to look at demographics in the workplace; she wanted to compare differently paid careers such as teaching and engineering and compare them in relation to gender and race.

The initial infographic Amber sketched had eight pie charts; one pie chart represented each category of gender and race for four different occupations. We, as the facilitators of the camp, discussed that Amber had promising data but that eight pie charts would be both visually unappealing and difficult to interpret. We

encouraged her to incorporate historical data, which she embraced. She was unable to find matching data for the different occupations and decided to focus on the demographics of working engineers. Her final infographic used a pictograph as well as a line graph to show how the field of engineering is overwhelmingly white and male and has been for the last ten years. After a few minor revisions, Amber's infographic was accepted for publication.

On the surface, Amber's case represents an ideal scenario for students in our project. Her experience at the camp further connected her to campus resources and networks of opportunity in STEM, strengthening her STEM identity, and she was able to articulate her growth in data literacy in her final presentation. Upon further analysis, however, Amber highlights why we as designers of learning opportunities must reflect on our goals and practices. Amber's initial idea for an infographic was to show different demographic data, including race and gender, for differently paid occupations. She seemed to have an intuitive sense that lower paid jobs are more likely to be occupied by women and minorities, a fact verifiable at the Bureau of Labor Statistics. Her complicated topic was both socially and personally relevant since she was interested in both art and engineering. Rather than support this complex idea, we, inadvertently, slowly chipped away at it until her final infographic presented data that showed engineering is predominantly white and male. Although this claim is not trivial, her infographic did not represent the depth of her apparent intuitive understanding, nor did the process allow her to deepen that understanding through analysis. Our data provide examples of missed opportunities to support her critical understanding of her data. For example, after narrowing in on the field of engineering, we encouraged her to represent historical data; however, she went back only ten years and her data represented the field as stagnant. Had we encouraged her to dig deeper, she would have seen that the number of women in computing has actually declined since the 1980s. In her final presentation Amber said it was "easier" to focus on only one occupation. By allowing Amber to make her work "easier" and not encouraging more effort, we must ask ourselves if we contributed to the common phenomenon of over-praising girls' ability, contributing to their lack of willingness to engage in complex tasks (Dweck, 1999).

Conclusion

Amber's case emphasizes why we as designers of learning must interrogate our own practices, and continually reassess our project goals and outcomes against the larger narratives of success and equity, particularly within STEM disciplines (Carlone, Haun, & Webb, 2011). Promoting Amber as a "success" of the SLI project only tells one side of the story; her statement on the last day was very prescient, there are, "so many different ways to represent and visualize the same amount of data, and how you visualize it will teach the public different things even if it is the same data." The summer camp provided a unique context to study our larger SLI goals. In our poster we further discuss our project decisions that were reaffirmed, challenged, and expanded.

Endnotes

(1) All proper names are pseudonyms.

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Acknowledgments

Developing a Language-neutral Instrument to Assess Fifth Graders' Computational Thinking

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Abstract: Computational thinking (CT) is critically important for students to develop in the 21st century. However, empirical work on the development and validation of assessment tools on CT, especially at the elementary level, is still lacking. In this study, we report our initial effort in designing and implementing an instrument to assess elementary students' CT.

Keywords: computational thinking, assessment, robotics, elementary students

Introduction

The term computational thinking (CT) was brought to public attention by Jeannette Wing, who argued that CT is a fundamental skill for everyone, not just for computer scientists, and it should be introduced early on to children in parallel with reading, writing, and arithmetic (Wing, 2006). CT is defined as "solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science" (p.33). Other definitions and interpretations have been proposed, but problem solving remains the cornerstone (Barr & Stephenson, 2011; Lee et al. 2011). More recent formulations emphasized that the representations of solutions produced through CT should follow computational conventions that can be read by machines (Aho, 2012). When describing the nature of CT, many scholars have emphasized its connections to other academic disciplines. For example, Bers (2010) argued that CT is "a type of analytical thinking that shares many similarities with mathematical thinking (e.g., problem solving), engineering thinking (designing and evaluating processes), and scientific thinking (systematic analysis)". The Next Generation Science Standards framework (NRC, 2012) listed "using mathematics and computational thinking" as one of the eight core scientific and engineering practices.

Different analytical frameworks have been proposed to delineate the dimensions or components of CT (e.g., Grover & Pea, 2013). Brennan and Resnick (2012) proposed three key dimensions of CT in the context of using Scratch (scatch.mit.edu): computational concepts (e.g., iteration), computational practices (e.g., debugging), and computational perspectives (i.e., the perspectives about the world around designers and about themselves). The U.S. College Board has recently put forward a curriculum framework for the AP Computer Science Principles Course, to be launched in the 2016-17 academic year (College Board, 2014). The framework proposed six core CT practices (connecting computing, creating computational artifacts, abstracting, analyzing problems and artifacts, communicating, and collaborating) and seven big ideas related to CT (creativity, abstraction, data and information, algorithms, programming, the Internet, global impact). Computer Science Teacher Association (CSTA) proposed an operational definition in which CT is a problem-solving process that entails formulating computer solvable problems, processing data systematically, abstracting, thinking in algorithms, addressing problems with efficiency, and transferring (CSTA, 2011).

Despite the proliferation of definitions and perspectives on CT, little empirical work has been done on assessing CT, especially at the elementary level. One challenge is that computer science has not been a core subject especially at the elementary level. Another challenge is that there is no consensus framework on operationally defining CT. It is also hard to conceive to use a generic instrument on CT to assess student learning in a language-specific computer science program (Web, 2010): when students have not learned the specific programming language, how can one assess their CT knowledge in a pretest so that we can measure their gains (compared with a posttest)? This is the research question we attempted to address in this study.

Methods

We developed an instrument to assess CT (the focus of this paper) as part of the evaluation system for a robotics curriculum that we developed for upper elementary school students. The semester-long curriculum uses the humanoid robot named NAO (by Aldebaran Robotics) that contains many sophisticated robotics tools, and more importantly, a drag-and-drop programming platform that is appropriate for elementary age students. The curriculum was adopted by a public elementary school in a southeast city in the United States. The school enrolled in 767 students in 2015 (Gender: 48.8% female and 51.2% male; Ethnicity: 40.8% Black, 24.8% Hispanic, 23.1%

White, 6.9% Asian, 0.4% Indian, and 4.0% two or more ethnicities). Their entire fifth grade (6 classrooms) adopted the curriculum.

The assessment instrument includes 23 items (15 multiple choice and 8 constructed-response items) in six problem sets. To make sure our instrument assesses CT, we explicitly identified the CT components each item assesses. The components include: (1) forming computer executable solutions with correct syntax, (2) logical data processing, (3) consistency among external representations, (4) algorithmic thinking, which involves modularization and flow control, (5) efficiency of the solutions. There are two different types of contexts for the problem sets (Figure 1): Type I context uses everyday scenarios such as washing cloths and driving and Type II uses robotics as a context to write or evaluate computer codes. For Type II items, we further developed two forms of otherwise identical items: Form A uses a text-based programming language and Form B uses a drag-and-drop programming language. A different set of Type II items will be used in posttest to match the robotics curriculum. On both forms, we introduced the programming language in an age-appropriate way. These items were initially developed by the research team, and reviewed by the fifth grade teachers, and piloted by a volunteer fifth grade student.

You are running 4 loads of laundry in a fast washing machine and each load of clothes takes 10 minutes to run….

A research team is developing a robotic arm that can draw shapes according to input commands….
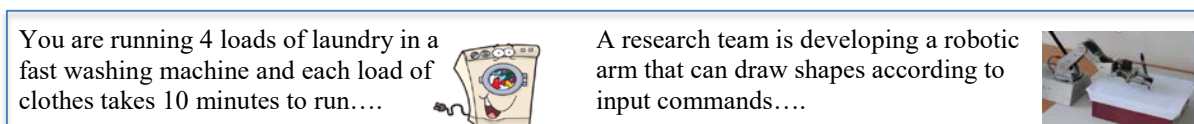
Figure 1. Sample items in two different contexts: everyday scenario (left) and robotics context (right).

We administered the instrument (in paper/pencil) as a pretest in September 2015 (the posttest will be collected in late spring 2016). A total of 121 students from six 5th grade classrooms took the pretest. Each student was randomly assigned to either Form A or B. The results were analyzed using a Rasch testlet model.

Findings from the Pretest and Implication

Here we highlight some notable preliminary results from the pretest. The item difficulty level had a wide range (e.g., from -1.911 to 1.269 in logit scale) and student performance also spanned a wide range. The whole instrument has a EAP/PV reliability of 0.808 and Person separation reliability of 0.979. There was no significant performance difference between the two forms ($t(119)=0.556$, $p=0.579$). This leads to an interesting question: given the robotics curriculum uses a drag-and-drop programming environment, will students perform better in posttest in Form B? Most of the students did not have a good algorithmic strategy when solving multitasking-based items - they tended to apply serial thinking. In terms of external representations of solutions, many students preferred more concrete representations (numeric values, natural language, etc.) to higher levels of abstractions (algebra, codes, etc.). Many students also did not pay much attention in terms of generating machine-executable solution (i.e., syntax). Some students were very creative in forming unexpected solutions, which challenged our current formulation of CT. We will be able to report both pretest and posttest results in follow-up analyses. We believe our study will shed light on how to assess elementary students' CT in a language neutral way (apply as pre/post evaluation).

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New Creativity Examined With E-Textiles: Bridging Arts Craft and Programming

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Abstract: Children in the digital age can express their ideas in both physical and digital spaces. Electronic textiles, or e-textiles, using the LilyPad Arduino provides opportunities for children to explore their design possibilities and to actualize their imaginations into physical objects. This work-in-progress study examines primary students' creativity as they engage in designing and implementing e-textile projects in the fifteen-week school club activities. This study aims to unpack the emergence of primary students' creativity in terms of technical, critical, creative and ethical practices of production.

Keywords: arts craft, programming, e-textiles, new creativity

Introduction

Children in the digital age can incorporate emerging technologies into their creative problem solving procedures both in schools and outside schools. In addition, children are expected to fluently express their ideas in both digital and physical environments. Recent development of construction kit called the LilyPad Arduino opens a door for children to express their ideas into physical objects that behave as they would like them to do through computations (Buechely, Peppler, Eisenberg, & Kafai, 2013; Buechley, & Qiu, 2013).

In this study we attempt to examine the emergence of children's creativity as they participate in 15-week 'arts and programming' club activities. The projects in the club activities are designed to enable children to explore new possibilities to express their own ideas/styles and to appreciate the value of computations and programming in their artistic endeavors. The study will uncover how children leverage the interface between programming and arts craft, and blend them together for meaningful and functioning creations.

Methods

Participants and research context

The participants are from a private school located in Seoul, Korea. The students in the school are overall high achievers and their parents maintain a high level of interests for their children's school performance. The participants of the 'arts and programming' club experienced Scratch programming at their 3rd and 4th grade, and Smart robots (Atti Inventor) at their 5th and 6th grade. Currently, 5th and 6th graders in the school are using 3D modeling software (TinkerCAD) and 3D printers. The participants for this study include eight 5th graders (five boys and three girls) and seven 6th graders (four boys and three girls) on a voluntary basis.

Course structure

The class of 'arts and programming' club meets every Wednesday. The club activities include 15 lessons for 15 weeks and each lesson takes forty minutes. In the club activity, students design objects that they use in their daily lives like bookmarks, bracelets, cushions and other products of their interests using the Lilypad Arduino. They complete one project in three to four weeks. The first three project themes are adopted from a Lilypad book and the flow of lessons are provided in Table 1 (Buechley, & Qiu, 2013). Two more projects are included for students to select a theme for their own interests using LED, sound and light sensors.

Table 1: The project themes and flow of lessons in the 'arts and programming' club

Project Themes	The Flow of Lessons	Examples
1. Design my own bookmark Focus: Expression of light	☐ Understanding how a Lilypad works ☐ Sketching ideas to make a bookmark ☐ Sewing and Completion	
2. Design a DIY bracelet Focus: Expression of light and patterns	☐ Learning how to use a LilyTiny ☐ Sketching ideas to make a bracelet ☐ Sewing and Completion	

3. Design a monster cushion Focus: Expression of light and sound	☐ Learning how to program a Lilypad ☐ Sketching ideas to make a cushion ☐ Programming ☐ Sewing and Completion	

Analysis

<u>Qualitative analysis</u>

Artifact-based interviews (Brennan & Resnick, 2012) on students' projects have been conducted and transcribed for qualitative data analysis software. In addition, students' journals, program codes, and their workshop sheets for the theme selection and sketches in each lesson or project haven been collected for an in-depth understanding of students' creation activities and thinking processes.

<u>Quantitative analysis</u>

The students' projects are evaluated by a rubric developed in this study. The rubric incorporates relevant elements from the framework for interest-driven arts learning (Figure 1) which is comprised of four domains : a) technical (coding, debugging, repurposing), b) critical thinking (observing & deconstructing media, evaluating & reflecting, referencing, reworking & remixing), c) creative thinking (making artistic choices, connecting multimodal sign systems), and d) ethical practices (crediting ownership, providing inside information, respectful collaboration and sharing) of production (Peppler, 2013). Students' motivation for programming, attitudes toward software education, expectations and previous experiences are also collected.
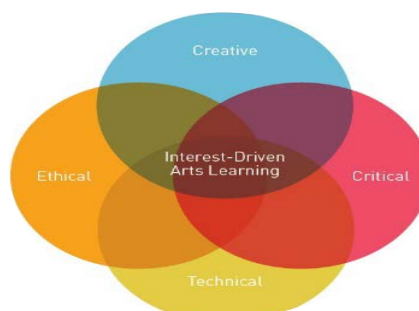
Figure 1. Interest-driven arts learning (Peppler, 2013, p. 22).

Learning outcomes and findings

This study sets certain expectation on learning outcomes: (1) students find ideas to incorporate computation and programming in the arts craft domain; (2) students realize the basic principle of programming and design and implement the physical objects that they can use in their daily lives; (3) students develop and improve their aesthetic expression and creativity through programming; and (4) students notice or search the overlapped area between programming and arts, and blend them (i.e., principle of arts such as pattern and symmetry, principle of computations). The study is in progress but children enjoy the time of creations especially when the art crafts respond as they are programmed. Comprehensive research results will be presented at the conference.

This study provides the case example of using e-textiles workshops to primary students in terms of technical, critical, creative and ethical practices of production. In addition, this study uncovers how children appreciate the role of programming and computation in providing useful functionality to their creative art crafts.

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A Cross-Cultural Study of the Effect of a Graph-Oriented Computer-Assisted Project-Based Learning Environment on Students' Argumentation Skill

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Abstract: The purpose of this mixed-methods study was to explore how 7th graders in a suburban school in the United States and 6th graders in an urban school in Taiwan developed argumentation skills in a project-based learning environment that incorporated a graph-oriented computer-assisted application (GOCAA). In each country, verbal collaborative argumentation was recorded and the students' post essays were collected. A one-way analysis of variance (ANOVA) was conducted for each measure of argumentation skills and a significant treatment effects on counterarguments and rebuttals was observed among the U.S. students, while in Taiwan, a significant treatment effect on reasoning and rebuttals was observed. A qualitative analysis was conducted to examine how the graph-oriented, computer-assisted application supported students' development of argumentation skills in different countries. This study found distinct argumentation patterns between the U.S. and Taiwanese treatment teams.

Introduction

The *Next Generation Science Standards* (NGSS) (National Research Council, 2012) identified "engaging in argument from evidence" (p. 12) as one of the essential eight science practices for students in the United States. As a common practice for scientists, argumentation is a process for constructing explanations and identifying solutions. A number of researchers (Kuhn, 1993) have defined essential elements of argumentation: position, reason, evidence, counterargument, and rebuttal. A position refers to an opinion or conclusion on the main question that is supported by reason. Evidence is a separate idea or example that supports reason or counterargument/rebuttal. Counterargument refers to an assertion that counters another position or gives an opposing reason. A rebuttal is an assertion that refutes a counterargument by demonstrating that the counterargument is not valid, lacks as much force or correctness as the original argument, or is based on a false assumption.

Recent studies (Scheuer, Loll, Pinkwart, & McLaren, 2010) have explored the potential of graph-based computer programs in improving learning outcomes and facilitating cognitive processes. The present study addresses the limitations of existing research (Dwyer, Hogan, & Stewart, 2012) on graph-based computer programs by engaging students in a project-based learning environment that involves using a computer-assisted program to support collaborative argumentation. Additionally, research indicates that cultural differences might have an impact on the argumentation process (Kim, Anderson, Miller, Jeong, & Swim, 2011).

The following research questions were addressed:

1. What are the differences in argumentation skills (as measured by reason, evidence, counterargument, and rebuttal) between students in a project-based learning environment that incorporates a graph-oriented, computer-assisted application (the treatment condition) and students in a project-based learning environment without such an application (the control condition) in each respective country?

2. How does a graph-oriented, computer-assisted application support students' development of argumentation skills in different countries?

Methods

This is a mixed-methods study. A total of 42 students comprised the treatment condition and were engaged in a project-based learning environment that incorporated a GOCAA. Of these 42 students, 21 were located in the U.S. and 21 were located in Taiwan. A total of 26 students comprised the control condition and were engaged in a project-based learning environment without this GOCAA. Of these 26 students, 15 were in the U.S. and 11 were in Taiwan. In both conditions, verbal collaborative argumentation was recorded with a digital camcorder. After one week of the argumentation activity, the students in both conditions were asked to write post essays. The topic was, "If the US (Taiwan) could fund only one form of alternative energy, which one should you select?" In

addition, based on Kuhn's (1993) definition of individual argumentation skills, the students' essays were scored for argumentation skills. The researchers followed the frameworks suggested by a number of studies (Kelly & Crawford, 1996) to analyze how the computer-assisted application supports the collaborative argumentation process.

Findings

Research question 1 asked whether, in each country considered separately, students from the treatment condition differed from students in the control condition in argumentation skills. A one-way analysis of variance carried out on each of the outcomes showed a statistically significant effect for the treatment condition for the counterargument [$F(1,34) = 3.92$, $p = .001$] and rebuttal [$F(1,34) = 12.37$, $p = .001$] outcomes in the U.S., with scores in the treatment group (M=2.00, SD=1.18; M=2.00, SD=1.45) higher than those in the control group (M=0.73, SD=0.80; M=0.53, SD=0.83). Effect sizes were large (η^2= .28 and η^2= .27), respectively. No statistically significant treatment effect was observed for the reasoning [$F(1,34) = 2.81$, $p = .10$] or evidence [$F(1,34) = 0.64$, $p = .80$] outcomes. A significant treatment effect was observed on the rebuttal outcome [$F(1,30) = 11.298$, $p = .003$] in Taiwan, with scores in the treatment group (M=2.70, SD=1.42) higher than those in the control group (M=0.73, SD=1.27). A marginally significant effect was observed on the reasoning outcome [$F(1,30) = 4.06$, $p = .05$], with scores in the treatment group (M=5.50, SD=3.63) higher than those in the control group (M=2.82, SD=2.40). Effect sizes were moderate-to-large (η^2= .19) and large (η^2= .37), respectively. No statistically significant treatment effect was observed for the evidence [$F(1,30) = 0.85$, $p = .37$] or counterargument [$F(1,30) = 0.20$, $p = .66$] outcomes.

A qualitative analysis was conducted to examine how the graph-oriented, computer-assisted application supported students' development of argumentation skills in different countries. This study found distinct argumentation patterns between the U.S. and Taiwanese treatment teams. Additionally, there a distinct gender difference in the use of evidence and division of labor was noted when the Taiwanese teams were compared to the U.S. teams, which may be explained by cultural differences.

Conclusions and Implications

This study concluded that, in both the U.S. and Taiwan, a project-based learning environment incorporating a GOCAA was effective in improving students' developing their scientific argumentation skills. There is a need to examine what kind of support and whether the built-in support in the application is effective in developing qualities of good argumentation in students of different cultures.

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Acknowledgments

Becoming a Teacher Who Takes an Inquiry Stance

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Abstract: The poster explores the ways in which preservice teachers engage with the complexity of learning how to teach. Framed in Cochran-Smith and Lytle's (2001; 2009) construction of inquiry as stance, we explore the ways in which preservice teachers make moves to resolve and simplify, use procedures to inquire into their teaching, and grapple with complexity, moving in an out of inquiry spaces in many areas of their practice.

Keywords: pre-service teachers, inquiry stance

Introduction

Inquiry as stance signifies "a worldview, a critical habit of mind, a dynamic and fluid way of knowing and being in the world of educational practice" (Cochran-Smith & Lytle, 2009, p. 120) that transcends the confines of project-based research. It involves constant problematizing of current structures and assumptions. As teacher educators and researchers we are interested in: *How do preservice teachers become practitioners who engage in inquiry as stance? How does teacher learning that moves beyond certainty develop over time?*

Our investigation focuses on the narratives that preservice teachers construct as they reflect on their trajectory through a year-long urban teacher education program and their experiences in teaching linguistically and culturally diverse students in local schools. Based on an emergent coding scheme, our initial analyses suggested a range of engagement types in inquiry stance. In sharing our work through the proposed poster, we hope to engage researchers, teacher educators, and teachers in discussing the analyses and our evolving conjectures on the development of inquiry stance. The research contributes to a small but growing literature investigating the development of inquiry-as-stance in beginning teachers (e.g., Donnell & Harper, 2005; Wolkenhauer, et al., 2011).

Data and analysis

Our work takes place as part of a larger investigation into teacher learning as part of a research network within the Urban Teacher Education Consortium (UTEC) (1). Clark University's Teacher Education program is a one-year Master of Arts in teaching program embedded in a neighborhood-based, university-school partnership. Preservice teachers are immersed in a partner school for a full academic year, with aligned and integrated course work. Over the past three years, we have been using written interviews and reflective prompts to investigate preservice teachers' evolving conceptions of schooling, teaching practices, and students, as well as their sense of themselves as learners. Here we focus on interview data collected across two different cohorts (N = 8; N = 13) across the past two MAT years.

Although the interview protocol did not specifically focus on issues of inquiry, the preservice teachers responses indicated variation in the ways that they grappled with emergent issues. In an effort to begin to characterize this variation, we grounded our analytical lens in Cochran-Smith and Lytle's construct of *inquiry-as-stance* (1999). We categorized student responses using three broad categories:

- **resolution-oriented***:* involves simplifying complexity through solutions
- **procedural inquiry***:* involves taking a procedural approach to resolving questions or issues that arise, such as a step-wise procedure of problem identification, data collection, conclusion
- **grappling with complexity**: involves problematization and "staying with" inherent complexity

Findings

Table 1 presents examples of portions of pre-service teachers narratives in relation to the three broad categories. Kristin is faced with students who are struggling with their work and attempts to prioritize time and resources by identifying students who legitimately struggle and those that are "just choosing not to do it." Lauren describes working with a colleague to collaboratively determine effective lessons through cycles of testing and sharing "what worked." Kristin's and Lauren's descriptions of resolution through identifying students who need attention (*resolution-oriented*) and creating a procedure for determining good lesson elements (*procedural-inquiry*) seem likely to have been influenced by both university and school-site environments and their perceptions of what was expected of them as new teachers. Cochran-Smith and Lytle (2001) argue that inquiry as stance challenges the

dyad of novice-practitioner in teaching, one that pre-service teachers may feel acutely as they are often positioned as "novices"; as such their goal is to gain the skills and strategies to become "expert". This goal may stifle inquiry as stance by limiting inquiry to finite projects, or resolving complexity in order to define and acquire "best practices."

Notably, the instances in which preservice teachers appeared to move into spaces of deeper inquiry occurred in challenges involving issues of racial identity and relating to students, as reflected in Kyra's narrative. While the pressure of "best practices" exists in teaching, it is not clear that the pressure to resolve and simplify exists in conversations about complexity of race in education, which could explain the *grappling with complexity approach* that pre-service teachers like Kyra enacted in regards to race. This distinction raises questions as to how teacher education programs can cultivate development of an inquiry stance that moves beyond resolution and procedural inquiry in order to hold space for the complexity of teaching.

Table 1: Sample of Preservice Teacher Responses

Resolution Oriented	Procedural Inquiry	Grappling with Complexity
Kristin: …the *only legitimate reason I can think of for not doing something else for a kid… is that…you know that they can do it and their just choosing not to do it… if someone is struggling academically there's no reason that I shouldn't give them another worksheet or give them manipulatives or have them working in partner … I know they know the material and they're just refusing to do it.*	**Lauren**: *…I know one of the other girls in the program, she and I have had two very similar lesson plans and so we were like sharing materials because … we have to teach the same stuff…She did one of her lessons first so she told me what worked for her lesson and what she would change so that when I did my lesson I could take that into account and I did the same with her on another lesson..*	**Kyra**: *…you know in social studies we talk a lot about race, and we talk a lot about these issues so like, as a white person sometimes I'm like, well do I really even understand?*

Implications/Discussion

What we saw in our data was not "inquiry" versus "no inquiry", but rather indications of what might be emerging stances, as preservice teachers grappled with the complexity of learning to teach. Indeed, the narratives of many preservice teachers had representations across the three categories at different points in their narrative. As part of the poster discussion, we intend to engage participants in questions regarding the developmental trajectory of the stance of inquiry. Our data suggests that this trajectory is not linear, but rather entails movement in and out of inquiry spaces as preservice teachers attempt to address the various questions that emerge. We also want to raise issues of context and how the culture of schooling and of teacher education programs support or challenge the cultivation of a stance of inquiry.

Endnotes

(1)   http://www.clarku.edu/education/hiatt-center-urban-education/initiatives/networks-inquiry.cfm

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Creating a Safe Learning Environment for Peer Assessment: Exploring Students' Conceptions Towards Fading Anonymity Over Time

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Abstract: In this study students' conceptions (N = 45) towards fading anonymity within a face-to-face peer assessment setting in higher education are explored. The aim of the study is to explore how this approach affects students' level of importance towards PA. Results show that the importance attributed to anonymity decreases after consecutively experiencing an anonymous and a non-anonymous mode. Furthermore, students' general conceptions towards peer assessment positively augment from start to end of this intervention.

Introduction

In peer assessment (PA) the social context can be critical when student are interpreting assessment and feedback that they received, because PA "*does not happen in a vacuum; rather it produces thoughts, actions, and emotions as a consequence of the interaction of assessees and assessors.*" (Panadero, 2016). This includes possible reciprocity effects caused by interpersonal processes such as friendship marking and psychological unsafety (e.g. Vanderhoven, Raes, Montrieux, Rotsaert & Schellens, 2015). In order to acknowledge the possible influence of interpersonal processes that are described above, previous research has shown that providing anonymity for the assessors can lead to more positive conceptions towards PA (Vanderhoven et al., 2015). However if we keep these PA settings anonymous students will not experience enough direct opportunities to practice their evaluative expertise, which is an essential skill to become a self-regulated learner (Boud, Lawson, & Thompson, 2013). As an answer to this problem, in this study fading anonymity over time within a PA-setting is investigated. Students' conceptions towards this fading intervention will be explored, as it assumed that they will give us more insight in students' evolution concerning their PA conceptions and their attributed importance towards anonymity.

In our first analysis of the collected data, we focus on two research questions:

RQ1: What is the evolution in importance-level towards anonymity when students' experience an anonymous PA-setting with fading anonymity over time?

RQ2: What is the evolution in students' conceptions within this PA-setting?

Participants and setting

Participants in this study were 45 third-year Bachelor students in Educational Studies (M Age= 21). The majority were female (86.7%). The main objective of this course was to become acquainted with various instructional design strategies based on a social constructivist learning approach through authentic tasks (Tillema, Leenknecht, & Segers, 2011). Besides several theoretical lectures, students received a group assignment to prepare and present a workshop on one of the provided topics (i.e. The Jigsaw Classroom, Student Teams-Achievement Divisions, Teams-Games-Tournaments, Group Investigation and Peer Tutoring). The 16 groups consisted of two (3 groups) or three students (13 groups).

The assessment and feedback episode after each workshop session included the three steps: First, students gave anonymous scores and feedback on the given rubric scores via the free application Socrative in a WiFi-enabled classroom (via laptop, tablet or own smartphone), and, the aggregated results (on a 5 point-scale) were projected live onto a Smartboard (live feed). Second, after all students had responded, the given results were orally discussed with the peers (oral peer feedback). Thirdly, additional reflective remarks (for example "what could be the reason for…") on the projected scores and feedback could be given voluntarily by the students. Within a day, the Socrative reports (automatically generated Excel files) were sent to the assessed group. These episodes were repeated for four consecutive weeks.

In order to investigate students' conceptions towards the effect of fading anonymity over time, two *assessment modes* were created: in the first two weeks (i.e. 8 workshops) the students could give feedback to their peer anonymously, the last two weeks non-anonymously. The moment that the group had to organise their workshop was randomly assigned resulting in two *presentation condition*s (seen from an assessees' point of view). Due to our specific research interest on anonymity students were not informed in advance about the transition

from anonymous to non-anonymous. The possible change in conceptions could thus not have been influenced by foreknowledge.

Instruments

Data was collected via questionnaires before (Time 1), after the anonymous assessment mode (Time 2) and at the end of non-anonymous assessment mode (Time 3). All items were measured using a 7-point Likert scale, and anchored by 1 (*totally disagree*) and 7 (*totally agree*). Cronbach's Alpha of the used scales ranged between .85 and .91.

Results

A repeated-measures ANOVA shows that students' importance-level towards anonymity significantly decreased over time $F_{(2,78)} = 6.981$, $p = .002$). Contrasts revealed that students significantly attribute less importance towards anonymity at Time 1 compared to Time 3, $F_{(1,39)} = 4.74$, $p = .000$ (Mean difference = .50) and Time 3 compared to Time 2, $F_{(1,39)} = 4.735$, $p = .000$) (Mean difference = .97). Furthermore, there was no significant interaction effect between degree of importance to anonymity and the *presentation condition,* $F_{(2,78)} = 1.100$, $p = .338$. Additionally, a one sample t-test showed that all students had a 'neutral' stance towards the importance of anonymity within PA at Time 3: the mean score did not differ significantly from the neutral 4 on a 7 point Likert-scale, $t(22) = .844$, $p = .408$ (anonymous presentation condition) and $t(19) = 1.293$ $p = .211$ (non-anonymous presentation condition).

The repeated measures results of the second research question show that students' conceptions increased over time $F_{(2,70)} = 13.301$, $p = .000$) (Assumption of sphericity has been met: Mauchly's W $p = .44$). Contrast analyses show that students' conceptions towards PA become significantly more positive after Time 2, $F_{(1,35)} = 13.565$ $p = 0.001$ (Mean difference = .49) and slightly rises after Time 3, however this difference is non-significant, $F_{(1,35)} = .586$, $p = 0.238$ (Mean difference = .14). Students' conceptions towards PA significantly increased from time 1 to time 3 $F_{(1,35)} = 21.293$, $p = .000$ (Mean difference = .63). No significant interaction effect was found with the presentation condition, $F_{(2,70)} = 0.324$, $p = .724$.

Significance of the study and conclusion

The preliminary results of this study indicate that fading anonymity for the assessor over time within a face-to-face PA and feedback setting decreases the importance that students award to anonymity. This results in a neutral stance towards anonymity (RQ1). This is an important finding in our search for educational interventions that support the development of students' evaluative skills. Additionally, the positive trend in students' conceptions towards PA (RQ2), gives an indication that the anonymity in a PA-setting can fade to a non-anonymous setting, without leading to more negative conceptions towards PA. Therefore, a fading intervention might be a good approach to assure a safe environment for PA at the start, while allowing PA in a more authentic setting without negative feelings at a later stage. Future analyses will focus on the qualitative data that was collected in order to deepen our understanding about student' attributed importance towards anonymity in PA.

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The Lonesome Penguin: Voice Created Through Language, Identity, and Engagement in Climate Science

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Abstract: This study follows 4th and 5th grade participants in an after-school program in a predominately Latino community. In the after school program, youth created films as part of a co-design process in which they were tasked with creating learning tools for teaching younger students (2nd and 3rd grade) about climate change. Rooted in socio-cultural perspectives, this work positions learning as a social process that is created by the learner's community. We examine how language, identity, and engagement in climate science allowed for youth voice on- and off-screen. To explore these issues, we focus on case studies of students and describe how taking on-screen roles allowed for youth agency in both science and their social groups.

Keywords: informal learning environments, language, identity, voice, engagement, climate science, underrepresented community

Learning is not just about developing the practices of experts, as described in vertical learning; it is about recreating those practices in locally meaningful ways. This stance on learning demands that we consider the role of agency in youth development (Barton, Tan, 2010).

Introduction

There has been an increase in national efforts to encourage science, technology, engineering, and mathematics (STEM) participation, especially in underrepresented student populations. Research has included broadening participation of underrepresented student populations in STEM through informal environments. In addition, there has been an emerging focus on language and literacy in STEM education due to the large influx of bilingual households in the United States (Stoddart, Pinal, Latzke, & Canaday, 2002). This educational concern becomes even more urgent when tied to the ongoing societal impacts of a changing climate; climate change education has become a focus of educators, but increasing community voice and agency for those most affected by climate change remains slow. Emerging climate studies predict alarming global effects that will have severe negative consequences, and these consequences are the most impactful for communities with fewer resources (Intergovernmental Panel on Climate Change, 2013). New standards and reforms in education have sought to address both the issues of underrepresentation and the urgency of climate change education. The Next Generation Science Standards (NGSS) included climate change in the K-12 performance expectations. In addition to incorporating climate change, the NGSS also prioritizes cohesion between other subjects (NGSS, 2013); indicating that because students learn about their natural world through different subjects, there must be an integration of science with math, social science, and communication.

This work exists in the nexus of these concerns as we examine how Latino/a youth engaged with an after school experience designed to promote youth agency and voice related to climate change. Our goal is to provide insight into the processes of engagement and identity construction through a co-design experience that provides opportunity for students to communicate through multiple languages. This experience focuses on supporting STEM participation, with a specific emphasis on climate change, for youth from underrepresented communities and bilingual households.

Methodology

The study used a critical ethnographic approach that includes a cross-comparison case study (Merriam 2002). This approach allows rich dialogical data sources that can be described through a culture-lens.

Study context

Martin Luther King Jr. (MLK) Elementary contains a large student body that is part of a predominately Hispanic community. MLK is located in a South San Francisco Bay Area community. According to the 3-Year API School Report., over 97% of students were socio-economically disadvantaged during the 2013 school year. From this population, our study focuses on twenty-six participants drawn from the 4th and 5th grade level of MLK's after-school program. Data sources include video recorded observations over the 16-week semester, interviews (group

and one-on-one) with youth, qualitative field notes, and curricular artifacts including student films and storyboards.

Due to the rich data set from two specific student groups, the eight participant members of those groups are included in a case study for comparison between group interactions. The students were chosen to be used for the cross-comparison study based on their consistent attendance, which provided a richer data set. Of the eight students, two strong female leaders are analyzed in detail.

Qualitative analysis

Analysis of data is currently in progress. Data is being analyzed using an iterative, emergent strategy (Gee, & Green 1998). Transcripts of these observations, interviews, and field notes are coded initially to identify themes. After this initial coding, the data is being recoded after revisiting each of the films and perspectives. This level of fine-grained data is important for the construction of a "thick description" of a situation, the aim of ethnographic analysis (Geertz, 1973).

Findings

Preliminary analyses foreground several important characteristics of the after school space as central to youth voice, including the opportunity to use multiple language resources to engage in the activities, and the use of film and roles to take on varied identities. Findings to date are briefly discussed for two groups: *Las Hermanas*, a group of four girls who had a common bond as members of a scout troop, and *La Fraternidad*, a group with three boys and one girl, Didi.

1. *Las Hermanas*: *Language as a mediator of participation*. The use of multiple languages emerged as a means of navigating through science content and understanding for the girls in *Las Hermanas.* Emergent themes include the use of multiple languages as a means for navigation through science content and understanding. *Las Hermanas* generally used Spanish for instructional and disciplinary discourse. Most of the scientific communication was done in Spanish, as students drew on their language resources to make sense of the material. This is distinct from other student groups who generally used Spanish for social purposes only. This construction of scientific understandings in Spanish is notable as participants told us that not being able to speak about science in Spanish was a barrier to engaging in science talk in the home.

2. *Las Fraternidad: Agency through on-screen roles.* The Lonesome Penguin is a character played by the most influential member of the *Las Fraternidad* group, Didi. Her character played the villain that attempted to drive the polar bears extinct in their iMovie, *Furious Fur: The Revenge of the Lonesome Penguin.* In our observations of the group, Didi at first appeared to be the leader of the group, but upon analysis, we found that many of the interactions with the other group members involved teasing, or her opinions were neglected. When asked about why her character had the name it did, Didi replied: "Because I'm lonely." Didi, however, used her onscreen role to enact a confident character, who was in control of the others in her group, while in the group off-screen she perceived that she had less agency.

Conclusions and implications

Future analyses target group dynamics and how they are defined with the two different female leaders. We will examine the influences of the initial experiences of the participants with climate science topics prior to the co-design experience, and how the students' leverage these experiences to inform their films. These results will have implications for designing learning experiences to promote agency and voice in science education.

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Refinement of Semantic Network Analysis
for Epistemic Agency in Collaboration

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Abstract: The purpose of this study was to improve semantic network analysis for shared epistemic agency in collaboration. A prior study demonstrated that one indicator, change in degree centrality, detects target epistemic actions with 60% accuracy. To improve this accuracy, we calculate betweenness centrality as well as degree centrality. Comparative analysis shows that the new indicator detects target epistemic actions with 83% accuracy.

Introduction

In the learning sciences, particularly in the knowledge creation metaphor of learning (Paavola & Hakkarainen, 2005), intentional engagement by students in collaborative learning (including collaboration skills and intrinsic motivation) is discussed in terms of epistemic agency (Damşa, Kirschner, Andriessen, Erkens, & Sins, 2010; Scardamalia, 2002). Students in collaborative groups engage in epistemic actions of (1) recognizing lack of knowledge, (2) alleviating lack of knowledge, (3) creating shared understanding, and (4) generative collaboration. Because agency in collaborative learning should appear at either the individual level or the group level across different time scales, any single analytic approach would be unable to cover both. In this study, we examine a new analytic approach to epistemic agency from the perspective of the "productive multivocality approach" (Suthers, Lund, Rosé, Teplovs, & Law, 2013). An assumption of the multivocality approach is that we can advance our knowledge in the learning sciences through the challenge of converting different epistemologies that usually make independent contributions into an interdisciplinary approach that is complementary in an integrative manner.

In the multivocality approach in our previous study (Oshima, Oshima & Fujita, 2015), we used semantic network analysis (SNA) to quantitatively detect pivotal points for further in-depth discourse analysis of how students engage in epistemic actions, assuming that we could represent collective knowledge advancement as structural change in a network of vocabulary in student discourse. The structure of vocabulary refers to meaningful links between words in an exchange. When students used words in their exchange, we assumed that they were attempting to create meaningful links between their words. We visualized a temporal network structure of vocabulary and calculated network indicators. To detect epistemic actions toward alleviating lack of knowledge, we paid attention to the transition of the sum of *degree centrality*. Degree centrality is a measure of how many nodes are linked to a specific node. In other words, the degree centrality is the network structure density. We assumed that a remarkable increase in the sum of degree centrality of all nodes in a network from one discourse exchange to the next indicates that the latter exchange either made an existing network denser or restructured it by adding new words to make it more robust. A higher sum of degree centrality was taken to indicate above the average actions toward alleviating lack of knowledge.

Although we succeeded in detecting epistemic actions, some of the detected exchanges were not actions toward alleviating lack of knowledge but rather indicating awareness of lack of knowledge. In this study, we attempted to improve the appropriateness of the SNA indicator for distinguishing between epistemic actions for alleviating and awareness of lack of knowledge. To that end, we consider a new indicator and tested its appropriateness by comparing the performance of the new procedure with our prior one for detecting epistemic actions.

Methods

We used the same dataset as in our prior study (Oshima et al., 2015) to examine the appropriateness of our new procedure. We extended our procedure by combining *betweenness centrality* and *degree centrality*. As discussed above, degree centrality is a typical measure for examining network structure density and robustness. In contrast, betweenness centrality indicates how each node in the network mediates others. Through review of results in our previous study, we found that learners were involved in exchanging their primitive ideas before alleviating lack of their knowledge. We considered that such learners' exchanges could be represented as fluctuation of the betweenness centrality. In our new procedure, we used these two centralities to detect discourse exchanges with drastic changes in the sum of degree centrality that occurred only when there was fluctuation in the sum of betweenness centrality before the change (Figure 1, left). We assumed that students might engage in discourse

exchange to reflect on their current understanding after becoming aware of their lack of knowledge. Such actions would increase only a small number of links but mediate other nodes more intensively.
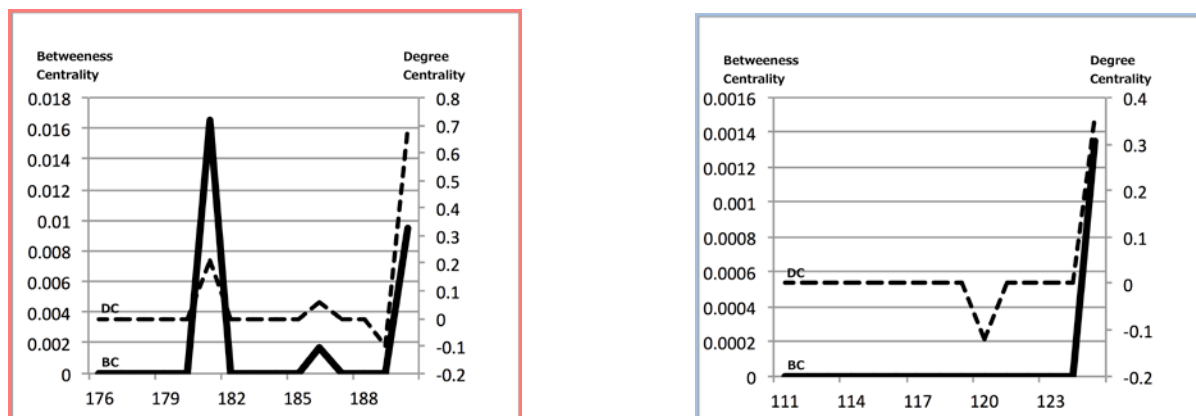
Figure 1. Changes in sum of degree centrality and betweenness centrality
for alleviating lack of knowledge (left) and others (right).

Results and discussion

Comparative analysis of discourse by one group suggests that our new procedure combining betweenness and degree centrality is significantly better than our previous indicator using degree centrality alone. The previous procedure detected ten discourse exchanges as pivotal points for alleviating lack of knowledge, six of which were identified as epistemic actions by in-depth discourse analysis. Our new indicator reduced the number of exchanges detected to six, five of which were appropriately identified. Thus, the detection rate accuracy improved from 60% to 83%. Comparative analysis of the two procedures shows that the new procedure using betweenness centrality alongside degree centrality reduced type I errors in detecting epistemic actions in discourse by 75% (three of four exchanges were not identified as epistemic actions). We have not yet examined the possibility of type II errors that the procedure misses certain pivotal points in discourse. A future analysis will examine these issues in parallel through SNA and in-depth discourse analysis.

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Designing Extensible and Flexible Augmented Mobile Learning Digital Lessons

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Abstract: This poster presents a model for augmented mobile learning used as part of a Croatian mobile learning research project. The project seeks to transform primary school teaching and learning experiences via novel tablet computer application approaches. The paper presents the design of modules for augmented mobile learning that are to be used on multiple mobile platforms as part of digital mobile learning lessons developed in the project.

Introduction

In educational contexts, through spatial visualization and interaction, Augmented Reality (AR) provides a unique experience which combines real-world and virtual information, making abstract concepts concrete for pupils (Billinghurst & Duenser, 2012). Using AR in education via Augmented Reality Learning Experiences (ARLEs) can lead to increased pupil motivation, with changes in engagement and behavior noted for pupils having previous motivation and concentration issues (Dunleavy, Dede, & Mitchell, 2008). Best practice for ARLE design is participatory iterative design with teacher involvement, respecting the principles of integration, empowerment, awareness, flexibility and minimalism (Cuendet, Bonnard, Do-Lenh, & Dillenbourg, 2013).

ARLEs have not so far been tested in the Croatian education system. Therefore an ARLE framework was developed as part of the SCOLLAm research and development project which explores mobile learning in the Croatian primary school context (Čarapina et al., 2015). The ARLEs in the framework are tailored to the specific curriculum and are designed utilizing the aforementioned best practices and principles of ARLE design.

An architecture for extensible and flexible augmented mobile learning

The SCOLLAm ARLE framework is based on configurable ARLEs, where each ARLE is a separate component that can be used as part of a SCOLLAm mobile learning digital lesson. ARLEs communicate with lessons through TinCan API-derived input and output parameters. Utilizing this approach, ARLEs can be reconfigured for different content contexts and levels of complexity appropriate for a specific digital lesson without changing the ARLE's code. Development is performed using the Xamarin platform, allowing for a multiplatform approach with significant code reuse, with native code used when necessary (see Figure 1).
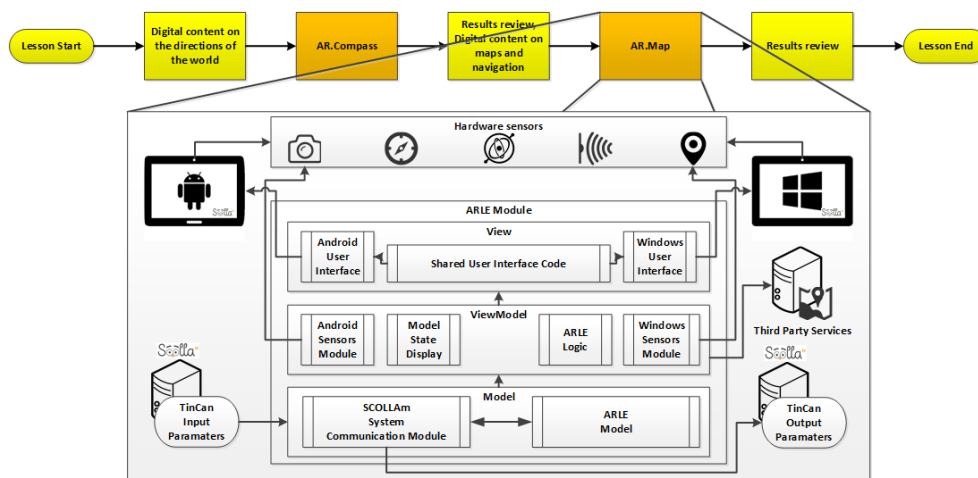
Figure 1. An example of a SCOLLAm digital lesson with the architecture of an ARLE module shown in detail.

Currently, there are three SCOLLAm ARLEs for Android and Windows operating systems being developed.

Extensible and flexible mobile ARLEs

AR.Shapes

AR.Shapes is used to teach shapes. A configurable list of shapes is provided (see Figure 2), where each represents a physical object in the environment with an affixed QR code to be scanned. Pupils progress when a correct shape is identified and are warned when a wrong shape is selected.

AR.Compass

AR.Compass educates pupils on the directions of the world by asking them to turn the tablet towards a specific direction. If their choice is correct, a configurable supplemental fact about the direction is shown (see Figure 3). If their choice is not correct, a hint is given, allowing for reinforcement in the physical context relevant to the classroom, local geographic area/landmarks etc.

AR.Map

AR.Map is used to explore the pupils' competencies in spatial orientation and map reading. The ARLE can be configured with coordinates of a number of locations shown on a map (see Figure 4) or in an AR viewport (see Figure 5) that the pupils have to physically locate in the area during fieldwork.
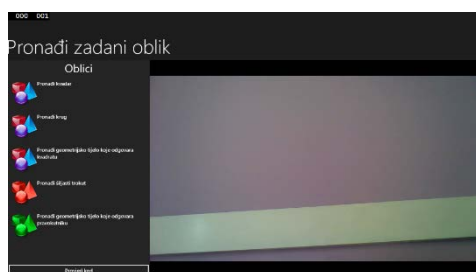
Figure 2. AR.Shapes identification of shapes
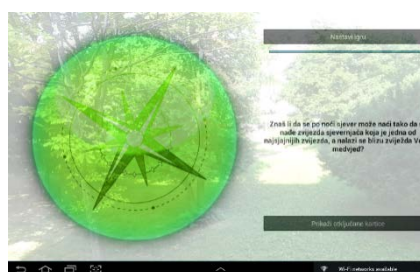
Figure 3. AR.Compass fact display example
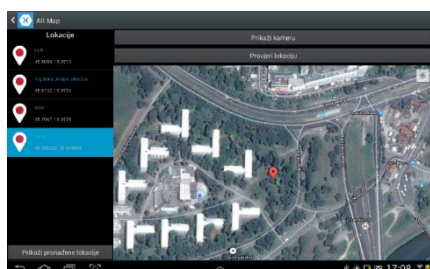
Figure 4. AR.Map map view with a list of locations
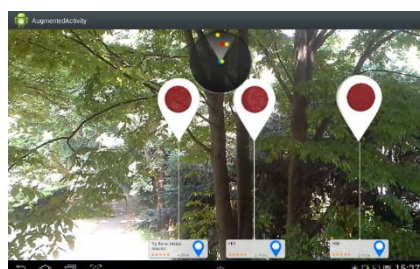
Figure 5. AR.Map AR viewport

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Acknowledgments

Knowledge Building and Conversational Functions in Online Interactions: A Coding Scheme

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Abstract: The aim of this study was to develop a coding scheme to analyze on line interactions in terms of "conversational functions", rooted in a KB model perspective. The coding scheme was created and used to analyze 10 messages written by 8 students in the first module of an online course. The inter-coder agreement was 76%, with Cohen's $K = 0,70$ at SCF level. The possible uses for future inquiry of this instrument are discussed.

Introduction

The Knowledge Building (KB) model by Scardamalia and Bereiter (2006) is oriented to the creation and improvement of knowledge of value to one's community. It is identified by 12 socio-cognitive and technological principles putting ideas to the center of classroom activities. A specific on line environment, Knowledge Forum (KF), has been created to support knowledge building activity. Considering the role of technology in the KB model, it is important to analyze how students interact in an on line environment. On line interactions can be analyzed in terms of Conversational Functions (CF), relating to specific kinds of activities performed in a discussion that support productive interaction (Wise, Saghafian, & Padmanabhan, 2012). The aim of the present study was to develop a coding scheme to detect on line interactions in terms of CF rooted in a KB perspective, identifying how students manage spontaneously some cognitive processes in KF.

Method

Participants and setting

Eight students attending the on line course of Educational Psychology at the degree course of Psychology at University of Valle d'Aosta. The on line course consisted of three different modules implemented with reference to the KB model, using KF.

Procedure

In order to build the coding scheme, connections between Scardamalia and Bereiter's (2006)'s KB model principles and Wise et al.'s (2012) CF approach were created. The development of the new coding scheme followed these steps:

1. Analysis of existing coding schemes and identification of Global Conversational Functions (GCF). Two existing coding schemes were considered: 1) the first one from Community of Inquiry model by Garrison and Anderson (2003), who define "Cognitive presence" in on line learning as articulated in 4 phases: Triggering event; Exploration; Integration; Resolution; 2) the second one by Cesareni, Cacciamani and Fujita (2016), including also relational aspects. With reference to this coding scheme we adopted the distinction among Global and Specific CF to identify the connections among CF and KB principles. Then, according to Garrison and Anderson (2003), we identified four GCF for KB, called Exploring, Providing Information, Re-elaborating and Evaluating. Finally, we identified some connections among the four GCF and KB principles (see Table 1).

2. Identification of Specific Conversational Functions. We selected from the coding scheme by Cesareni et al. (2016) the Specific Conversational Functions (SCF) focusing on cognitive aspects of the knowledge building process. The remaining SCF were combined, adapted and reformulated taking into account both the principles associated to the GFC and the aims of the present coding scheme (see Table 1).

3. Identification of Unit of Analysis and Application of coding scheme. The analysis unit were "segments", identified in each message by the punctuation (i.e. full stops, suspension dots, exclamations, and question marks). A total of 10 messages written in the first module of the course were taken into account. The segmentation of each message was managed by two independent judges, and the controversies were resolved by agreement between them. The coding scheme was then applied by the same two independent judges on the total of 54 segments detected. An example of coding scheme application by the two judges (judge1/judge2) is the following:"*Sorry F.M., but I have not understood this part of your intervention: (A/H) why the specialistic language could help non expert people? (A/A) The language used through which mass media? (A/A) And in*

addition what do you mean as "specialistic language"? (A/A) The theories? (A/A) Philosophy? (A/A) Sorry for so many questions...:-((I/H).

Table 1: Coding scheme: GCF and SCF with the definition and the corresponding KB Model principle.

GCF	SCF	KB Model Principles
Exploring	*A. Question or problem of inquiry*: questions concerning the course content, identified by question marks or interrogative expressions	*"Real Ideas, Authentic problems"*
	B. Hypothesis and ideas: possible explanation about a question or problem emerging during on line discussion	and *"Epistemic Agency"*
Providing information	*C. Applicative Example*: examples derived by the personal experience of the participant	*"Constructive Uses of Authoritative Sources"*
	D. Information from authoritative sources: theoretical information that is explicitly referred to a source	
Re-elaborating	*E. Repetition others' idea*: explicit reference to an idea of another member of the community	*"Improvable Ideas"* and
	F. Synthesis: synthesis of ideas of different participants	*"Rise Above"*
Evaluating	*G. Comment*: content evaluation	*"Concurrent, embedded and transformative assessment"*
	H. Metacomunication and Metacognitive reflection: evaluation or reflections on the strategies of work of the on line course	
Other	*I. Other*: all the functions not defined by the previous categories.	*None*

Findings

The inter-coder agreement of the two independent judges was 76%, with Cohen's $K = 0,70$ at specific CF level. The Confusion Matrix of the coding activity is showed in table 2.

Table 2: Confusion Matrix.

2nd judge	A	B	C	D	E	F	G	H	I	Total
1st Judge										
A	9									9
B		14		1	2			1	1	19
C			1							1
D				6						6
E		1			1					2
F						0				0
G							1		2	3
H	1							1	4	6
I									8	8
Total	10	15	1	7	3	0	1	2	15	54

Conclusions and implications

The coding scheme reached an excellent degree of agreement, showing its high reliability. However, it is necessary to extend the number of segments analyzed to have more robust results. The coding scheme can be used for the detection of some "emergent roles" in terms of CF, or the identification of the changes in the CF during the on line course. Also, it is possible to combine content analysis with quantitative analysis of interaction, to see how the CF can correspond to different socio-metric positions of the participants.

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Robotics Programming in Support of Computational Thinking: Scaffolding From Teacher, Peer, and Robotics Agents

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Abstract: This pilot study focused on learning task design of robotics programming to develop three key skills in computational thinking including abstraction, debugging and control-of-variables strategy, and investigated the scaffolding activities during interactions among teacher, students and robotics in the classroom. The preliminary findings suggest the designed learning tasks were appropriate for fostering CT skills development. In completing these learning tasks, different agencies played various roles and had their distinctive advantages in scaffolding different CT skills.

Introduction

Nowadays, computational thinking (CT) draws more and more attention from both educators and researchers, because it is one of the key competences in the digital age (Grover & Pea, 2013). CT involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science. To support development of CT competence, robotics programming is a frequently used learning media. In a robotics projects, students design and program robots with embedded code. They need to think about how the robotic agent will interact with external world based on perceptional data from its sensors and effects of its actuators. Benefit of robotics programming includes development of technological literacy, science literacy, programming skills, problem solving skills, and collaborative creativity, to name but a few (Slangen, van Keulen, & Gravemeijer, 2011; Sullivan, 2008, 2011; Wyeth, 2008; Barak & Zadok, 2009). However, there is a paucity of the science of learning research in designing age-appropriate curricula for computational thinking and/or robotics programming in K-12 education (Bers et al., 2014).

As Grover & Pea (2013) have suggested, in terms of socio-cultural and situated learning, distributed and embodied cognition, as well as activity, interaction and discourse analyses, the body of literature should be brought to bear on the 21-century CT research. To design and implement age-appropriate curricula of robotics programming for CT development, we should investigate the knowledge of CT, the utility of learning CT through robotics programming, the distributed and embodied cognition among children, teacher and robotics programming environment, as well as the distance between child's actual CT level and the level of potential development as determined through robotics programming under guidance, termed Zone of Proximal Development (ZPD). Therefore, this study focuses on scaffolding in primary school course of robotics programming, i.e., the process by which different agents or distributed cognition, such as teacher, peers and robotics, provide assistance that enables learners to succeed in robotics programming activities that would otherwise be too difficult. Specifically, the study proposed two research questions: first, what are age-appropriate learning tasks in robotics programming to support computational thinking competence development; and second, how can we scaffold primary students to overcome challenges in grasping computational thinking skills?

Methods

We conducted this first-round design-based research (DBR) in a primary school in Shanghai. The participants were the second grade students (normally 8-year old) attending a one-semester robotics programming course. There were 18 participants (3 girls and 15 boys) selected by their ICT teacher. Because this is the first time to implement robotics programming course in such an early age in this school, the teacher intentionally selected high academic performance students from parallel classes in the second grade.

The selected robot product for this course called iKnow can be programmed in a graphical programming environment (see Figure 1). In teaching robotics programming of early stage students, such as primary school students, graphical programming environment is ideal learning platform. It is relatively easy to use and can allow early experiences to focus on designing and creating, avoiding issues of programming syntax (Grover & Pea, 2013). In graphical programming environment, novices build programs by snapping together graphical blocks that control actions of a robot. iKnow robot can be programmed to make movement, light its eyes in different shapes (LED lights), be touched to make a sound or a move, sense light, sound, or the obstacles, as well as move along the pathway of different colors on the ground.

We assigned the eighteen participants into nine dyads. Each dyad will have one iKnow and a desktop computer for robotics programming. The course designed by the researcher of this study contains ten sessions

with sixty minutes per session. The course had one session each week and lasted for one semester. This pilot study focused on the first three sessions of the whole course.

Students in learning robotics programming often deal with qualitative knowledge (Barak & Zadok, 2009). For example, what is the effect of adjusting a specific parameter on robot's performance? How can robot be programed to achieve a certain goal? Bearing in mind the qualitative nature of robotics programming and CT competence as learning goals, design of learning tasks for the second grade primary students considers some fundamental skills of CT competence in relation with robot movement. Therefore, we designed three sessions to teach students the basic concepts in movement, such as speed, distance, moving forward and backward, turning left or right, moving in a curve line or around a circle, et cetera.

Preliminary findings, conclusions and implications

This study conducted the first round design-based research to investigate how robotics programming course can be designed to facilitate CT development in an early-stage primary school curricula. The preliminary findings of the classroom interactions among children, teacher and the robotics programming environment suggested the appropriateness of learning task design and scaffolding implementation for the purpose of three key skills mastering, i.e., abstraction, debugging, and control-of-variables strategy (CVS).

In this pilot study, we found that different CT skills require different scaffolding strategies. For example, the teacher played the key role in CVS and abstraction through direct instruction, asking prompt questions, providing just-in-time hints and creating transferrable learning contexts, but interactions of student-student and student-robotics agents may be a better way to improve debugging strategies. Compared with learning debugging skills which requires emerging problems in a dynamic situation, CVS and abstraction are more heuristic strategies and sharpening of these skills may require didactic instruction in combination with solving well-designed problems.

Further, the study revealed that the children could execute CVS to investigate different variables in a robotics system but have not yet developed the meta-strategic understanding of CVS (Lazonder, 2014). The finding corroborates the previous arguments that further study should focus on not only execution of CVS but also independent use of this strategy in student inquiry (Kuhn et al., 2008). Most children spontaneously engaged in learning debugging skills only if they were clear about the expected outcome. They can keep practicing, reflecting and practicing again in this robotics-afforded embodied cognition environment (Grover & Pea, 2013). Regarding abstraction skills, most children exhibited good performance in the tasks of this study under the guidance of the teacher. Future study should investigate children's competence of transferring abstraction skill to multiple domains or solving quite diversified domain problems. Unless iterative robotics programming curricula design and investigation in scaffolding activities during in-class implementation were conducted, we cannot guarantee the age-appropriated course to foster CT development in K-12 education.

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Developing Literary Reasoning Practices in Class Discussions

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Abstract: This study examines how students learn to engage in literary reasoning in a learning environment structured to make increasing demands on students to engage in disciplinary practices. Close attention to language in the text supports students' learning to interpret complex literary texts. Analyses of class discussions show student movement from guided analysis of textual evidence to reliance on their own analyses of text to support their interpretive claims and explore their own inquiry questions.

Introduction

Literary inquiry affords opportunities to explore perspectives, experiences, feelings, and ideas of others as well as to reconsider one's own perspectives and ideas about the world and human nature. Reading and interpreting literary texts involves ways of reasoning and understanding that make us more thoughtful about the world and our experience of it (Langer, 2011). Literary scholars approach texts to seek deeper meaning by attending to the language and structure of texts (Graves & Fredrickson, 1991) and entertaining multiple perspectives and possibilities for meaning (Earthman, 1992). Research on instructional interventions to support learning these practices indicates the importance of sequencing texts and tasks (Langer, 2011; Lee, 2007), providing students with opportunities to learn explicit strategies for literary interpretation (Lee, 2007), and using class discussions to build understanding (Applebee, Langer, Nystrand, & Gamoran, 2003; Langer 2011). This poster presents preliminary findings from analyses of three class discussions during one instructional sequence in the context of a ten-month study of how students learn the skills and practices of literary reasoning. The discussions were analyzed for changes in student practices in relation to differences in task structure and instructional support.

Methods

This research took place in the context of a multi-institution collaboration between researchers and practitioners investigating evidence-based argumentation with multiple texts in middle and high school history, science, and literature classrooms. The data for this study come from an 11th grade English classroom with 28 students in an urban school serving a diverse student population.

The overarching learning objectives for this class across the year were to analyze structure and language to make interpretive claims, support claims with detailed textual evidence, explain relation of evidence to claims and criteria, and synthesize within and among texts. The texts, tasks, and learning objectives were purposefully sequenced from simpler to more complex with decreasing instructional scaffolding. The specific data are from the second semester, which focused on the dystopian novel *The Handmaid's Tale* by Margaret Atwood.

Data sources include lesson artifacts, field notes, and video and audio recordings of classroom observations. Three whole class discussions, chosen based on related topic of inquiry, were analyzed for changes in student literary reasoning skills and practices across a four-week instructional sequence. The discussions were transcribed and coded for dimensions of literary reasoning, such as interpretive claims, types of evidence, connections between evidence and claims, and synthesis within or among texts. This coding was examined in relation to the opportunities and supports presented through the specific tasks and objectives of the discussions.

Findings

Analyses showed students engaging in literary reasoning practices with increasing independence across time. Table 1 describes characteristics, tasks, and supports of each discussion.

Table 1. Three discussions about moira

	# of Ss	Task	Materials/Support
Discussion 1: Analyzing a passage (23.5 min)	16	Discuss language author uses to describes Moira	• T-chosen passage from text • T-developed questions about passage
Discussion 2: Literary argument (23.5 min, 3 weeks later)	12	Discuss whether Moira is still a dystopian protagonist	• Completed paragraphs on Moira • T-chart on board
Discussion 3: Continuing the argument (17 min, 3 days later)	16	Discuss student questions in a student-led discussion	• Discussion topics brought up by students

In the first discussion, students analyzed a passage, chosen by the teacher, by making associations with particular language in the text and using those ideas to understand what that language indicated about the character. For example, when the author describes a character as "lava beneath the crust of daily life," the teacher elicits everyday understandings of lava from the students, including "hot" and "destructive," but another student pointed out that it "can create new land, a new beginning." These understandings of lava led to the conclusion that the character was "like motivation to them…putting them at risk for a good cause of having them be free."

In the second discussion, students debated a question posed by the teacher about whether or not the role of the character had changed across the course of the novel. The task involved finding relevant passages of text and explaining how those supported their claims. For example, one student pointed out: "Moira is not a person that is known for giving into the rules. […] Offred says 'She is frightening me now, because what I hear in her voice is indifference,' and Moira becoming indifferent is a problem. It shows her giving in. Once you become indifferent to a certain thing, it shows that you no longer care, or care enough to do something about it." Students also connected their claims to the criteria for determining a dystopian protagonist: "Even though she got caught she could still influence others to be, to act out of society and a dystopian protagonist is someone who acts out of society, not like others." The teacher guided the students as they explored multiple perspectives on the role of the character as well as on what constituted a dystopian protagonist.

In the last discussion, a student-led Socratic seminar, students chose to revisit the argument around the character, rejecting other potential topics, because it had been "a real good discussion" that they "never really finished." They engaged in similar practices, but this time with no teacher guidance. Students closely analyzed the language of the text: "'I don't want her to be like me, go along, give in, to save her skin.' It's saying how Offred is just doing it to benefit her own self and she doesn't want Moira to turn like that, just benefit herself and not help other people." They connect to criteria: "So it's basically trying to say like she don't want to stand out of the crowd, so she's not trying to be the dystopian protagonist, so she's trying to follow the crowd." Eventually the discussion turned to which of three characters might be the protagonist: "Moira kept doing it, and Offred kept doing it, and Ofglen was like I'm not going to do it anymore, so she gave her life up for what she believed in." However, not all students agreed: "It says 'So she's dead and I'm safe after all.' I don't think she is going to look up to Ofglen because like all she thinks about is her safety." This exploration of the characters and their roles in the novel in a student-led discussion demonstrates uptake of the literary reasoning practices modeled and highly scaffolded in the first discussion.

Across time, literary reasoning practices required less scaffolding, with the first discussion heavily guided by the teacher and the last led entirely by students. Students engaged in these practices independently to explore their own literary inquiry, indicating a trajectory of greater disciplinary engagement with less support.

Conclusions and implications

This research provides an example of how repeated practice and decreased scaffolding over time in whole class discussions can support students in learning to engage in the practices of literary reasoning with greater independence. The findings can be used to inform design of learning environments that support the development of literary reasoning skills and practices and empower adolescents to make sense of complex literary texts.

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Acknowledgments

Using a Systematic Review for Cross-Theory Comparisons

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Abstract: A solid theoretical foundation is essential for designing effective educational technology. However, different theories may offer competing recommendations, and it is important to balance multiple theoretical perspectives in technology design. In this poster paper, we describe how a systematic review methodology, traditionally used in the medical field, can be applied in a learning sciences context to identify student behaviors and learning conditions that are beneficial to learning. We present the process and early results by examining the overlap and discrepancies between knowledge building and inquiry learning theories as they relate to pedagogical best practices.

Keywords: systematic review, inquiry learning, knowledge building

Introduction

Educational technologies are becoming increasingly appealing for instruction; however, in order to develop effective instructional interventions, a solid theoretical foundation is critical. Theory provides a way of framing one's thinking, understanding and critiquing educational practices, and guiding actions. While literature searches and theory-based approaches are common across all forms of scholarship, they typically adopt a single theoretical lens. The selected theory then guides the choice and application of all other aspects of the research process, such as data collection and data analysis (Crotty, 1998). Adopting a single perspective is inherently incomplete and limiting (Abes, 2009), so rather than being confined by a single theory, researchers and designers should instead consider bringing together multiple theoretical perspectives. Cross-theory experimentation of this nature can lead to rich results and new possibilities.

This paper is part of a larger project where we combine multiple theoretical perspectives with a study of existing educational technologies and pedagogical practices to develop design recommendations. In this paper, we describe the first step of this process, conducting a systematic review to identify student behaviors and learning conditions that are beneficial to learning. A systematic review is a thorough and comprehensive methodology for conducting a literature review that locates existing studies, selects and evaluates contributions, analyzes and synthesizes data, and reports the evidence with clear conclusions (Denyer & Tranfield, 2009). It involves several steps including forming a research question, identifying databases to search, developing explicit search strategies, developing inclusion and exclusion criteria for selection of articles, and extracting data in a standardized format. Systematic reviews are common in medical research and have been used to develop evidence-based medical practice guidelines (Abbas, Raza & Ejaz, 2008). With the push towards more evidence-based practices in education, we see systematic reviews as an important methodology to apply to learning sciences. We intend to use this methodology across many learning theories, but as a first step, we have tested our methodology across two prominent theories: knowledge building (Scardamalia & Bereiter, 2006) and inquiry learning (Bruner, 1966). We show the promise of this approach through a brief qualitative synthesis of our initial findings.

Methods and results

The first step of a systematic review is to establish a clear and concise research question. Our research goal was to identify overlap and discrepancies between student behaviors and related learning conditions across a variety of learning theories. The second step is to locate and select studies by determining literature sources, identifying databases, formulating keyword search strategies, and developing inclusion and exclusion criteria. The literature search for this systematic review was restricted to journal articles published from 2001 to 2014. This allowed us to focus on recent technological developments and results. For our literature source, our search was restricted to the eight journals affiliated with The International Society of the Learning Sciences to keep the review process manageable. We conducted a search in the PsycInfo and Scopus databases using our university library's search engine on the abstracts of the papers looking for our target learning science theory keywords or their variations (e.g., "inquiry learning," "inquiry based learning," "inquiry-based learning").

The next step in a systematic review is to perform the search and screen the results using pre-determined inclusion and exclusion criteria. Since we wanted to combine theory with a study of existing educational technologies and pedagogical practices, our inclusion criteria required the abstract to mention: (a) A controlled

experiment, design-based research, or case study in a formal or informal learning environment that was designed using principles of the target learning theory, (b) Use of technology or an intervention, and (c) Analysis and discussion of results. We chose to limit the detailed analysis to ten papers per theory to balance between an exhaustive search and a sufficient count. While this paper details the methodology with only two selected learning theories, the overall project goal is to review ten theories of learning (approximately 100 papers). We prioritized diversity of authors, interventions, and publishing journal, in that order. Citation count was used to break ties.

To extract data in a standardized format, student behaviors were operationalized as individual or collaborative actions in which students engage that are beneficial to their learning. These behaviors are typically overt and observable as well as product-oriented and student-driven. Examples include students engaging in discourse, writing an explanation, and generating a hypothesis. Learning conditions were operationalized as events or situations that foster the productive behaviors with the intention of helping students in the learning process. Learning conditions tend to be process-oriented, instructor- or technology-driven, and domain-independent. Usually these conditions are provided in the form of assistance by the teacher or system agent; for example, a teacher asking open-ended, metacognitive questions or prompts provided by an agent to encourage reflection. We reviewed the selected articles focusing on explicit, author-identified behaviors and related conditions.

Next, we compared across theories, looking for overlap as well as discrepancies. One overlap we identified was that both theories argued that students should write or provide an explanation for their proposed solutions (Aalst & Chan, 2007; Song & Looi, 2012). In addition, both knowledge building and inquiry learning encourage the student to engage in the act of locating information and extracting relevant data for the given problem. There is a discrepancy however in how students should use that information. In inquiry learning studies, students used the information to construct evidence based arguments and justifications, whereas in knowledge building studies, students engaged in discourse around the information gathered and reflected on their own learning by comparing with others' work. Finally, studies under both theories encouraged teacher involvement, for example, by asking open-ended meta-cognitive questions to guide the inquiry with the common goal of developing deeper conceptual understanding. Technology that afforded a private space for individual note taking as well as some public space to share ideas with the rest of the group emerged as one common motif of this study.

Conclusions and implications

This research was grounded in the idea that as technology and pedagogy advance, a multi-theory approach is needed. To illustrate the promise of using a systematic review in learning sciences research, we conducted a systematic review to identify student behaviors and learning conditions in knowledge building and inquiry learning literature. We plan to review additional theories using the same methodology to develop a design framework. The findings will contribute to the knowledge base towards designing educational technology that effectively balances user needs with pedagogical theory and the affordances of advanced learning technologies.

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Acknowledgments

Effects of Knowledge Building Pedagogy on High School Students' Learning Perception and English Composition Performance

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Abstract: This action research was to investigate the difference in students' learning perception and in their performance of English composition. Participants were 39 high school students who were engaged in computer-supported knowledge building (KB). Data mainly came from questionnaires and students' writing works. Findings suggest that (1) students perceived KB as a better environment for creative learning, and (2) students' performance in English composition was improved in terms of # of words, and writing test scores.

Introduction

Learning environment has great influence on students' performance of learning (Collins, 1996; Lizzio, Wilson, & Simons, 2002). With the progress of the technology, almost all the classrooms are now well equipped with high-tech equipment. However, the question of how students perceive their learning environments relates to the assessment of their learning performance is rarely investigated. There are in general two types of learning environments. The traditional learning environment favors direct instruction pedagogy which can be commonly seen in Taiwan (Engelmann, Becker, Carnine, & Gersten, 1988). The other type of environment is more constructivist-oriented, favoring more student-centered activities and supporting more creative ways of teaching.

English is an international language and it is widely used in our daily life around the world. However, most Taiwanese students consider English composition as the most difficult part in learning English because it requires higher order thinking. English composition test has been put into practice in College Entrance Examination for years in Taiwan, but the results and outcomes of it are not as good as expected (Yang, 2003). The reason why students cannot perform well in their writing might be resulted from teachers' teaching pedagogy. In Taiwan, product-oriented pedagogy (POP) is perhaps the most commonly seen teaching method in a typical class, which mainly concerned about the correctness and the formation of the final (writing) product, simply asking students to imitate the grammatical and syntactical structures with repeated drill and practice. Studies indicated POP confines students' critical thinking and creativity development. It also makes students' works lack of vitality, as well as making them fear of writing (Chang, 2001).

As a result, constructing a good learning environment to assist students in mastering relevant knowledge and technique is important. Knowledge Building (KB) theory represents an idea-centered instruction. The teaching method aims to help learners with continual idea generation and improvement, as well as to engage them in intensive community collaboration (Scardamalia & Bereiter, 2003). Therefore, this study was designed based on KB pedagogy while using the technological platform of Knowledge Forum (KF), i.e., an innovative multimedia environment to support knowledge building in English writing. Using this pedagogy and environment, English composition pedagogy was implemented. Focusing on high school students, this study hopes to assist them to develop a better perception towards the designed English learning environment, to reach to a higher cognitive stage for writing, and to develop a skillful writing ability.

Methods

This study was conducted in a second-year high-school class (n=39) in New Taipei City, Taiwan. This study was conducted for ten weeks, with two lessons in each week totaling 1000 minutes with each lesson lasting for 50 minutes. Through knowledge building activities and its processes, the teacher conducted and guided the students from the basic stage of cognitive learning (knowledge memorization, comprehension, and application) to a higher stage (knowledge evaluation and creation). During the first two-lesson period, the teacher had a tutorial to all of the students first, aimed to enabling them to have a basic understanding of English writing and composition using an idea-centered knowledge building approach. Every time before moving to next steps, a set of self-designed KB scaffolds was provided (see Figure 1). After illustrating some regulations and guiding points of writing, the teacher engaged the students in idea-generating and improving activities in order to help them rise above their ideas on specific topics for writing. Then, the teacher asked students to communicate, discuss, and exchange these ideas with their group members respectively. Scaffolds were provided in-between all activities. After that, students individually did some reflection upon writing topics/issues/ideas, trying to rearrange their ideas/thoughts and

preparing for the next writing step/activity. In the end, each student had to complete their own compositions with more refined ideas. These activities with the same writing topics (but diversified and improved ideas) are conducted for about every three weeks so that students' English compassions and ideas could be revised and polished and improved again and again. This cycling instructional methods and scaffolds, which were collaboratively provided by the teacher, classmates, and environment, fit in with the main conceptual framework of knowledge building as writing ideas were continually worked and re-worked for improvement. As for data collection, a valid and published Knowledge Building Environment Scale (Lin, Hong, & Chai, 2012) and students' English composition were employed to enable data collection.

Findings

First, analysis of KBE scale was performed focusing on its three scale factors: "idea", "agent", and "community". Table 1 illustrated how students perceived their learning environment differently in terms of the knowledge building environment (KBE) group and the product-oriented environment (POE) approaches (note: students were asked to compared this KBE class using knowledge building approach with their previous POE class). The differences (see Table 1) were found significant, which showed that students perceived their current class environment as favorable for idea generation/improvement (t=-2.97, p<.01), and for community collaboration (t=-2.68, p<.05). Overall, students perceived their English writing class as a better environment for learning mainly because their ideas after generated can be freely and collaboratively improved in this class environment. And in terms of English composition, the results (Table 2) showed that the number of the total words was increased by 15 words on average, and the writing scores, which were assessed on a basis of the valid intermediate level standard of General English Proficiency Test (GEPT), were significantly increased by 0.33 points on average as well. That is to say, KBP was favorable for English composition performance. Moreover, students also expressed a positive and affirmative attitude toward KBP based teaching based on complementary interview data.

Table 1: Paired-samples t test in POE and KBE

| Factors | POP | | KBE | | |
	M	SD	M	SD	t
idea	3.69	0.56	3.98	0.59	-2.98**
agent	3.81	0.63	3.92	0.58	-1.29
community	3.69	0.63	3.97	0.67	-2.68*

*p<.05，**p<.01，***<.001

Table 2: Paired-samples t test in POP and KBP

| items | POP | | KBP | | | |
	M	SD	M	SD	t	increase
words	119	35.74	134	43.57	1.92	+15
words(120)	1.59	0.50	1.65	0.48	0.63	+0.54
grades	3.39	1.08	3.72	0.97	1.83	+0.33

*p<.05，**p<.01，***<.001

Conclusions

The study suggests that learning using a knowledge building approach is conducive to making students perceive their course environment as more favorable for idea work and for collaboration. They see ideas as some tangible objects that can be expressed, interacted, comprehended, and integrated in a KBE class. Additionally, they also believed members' participation and collaboration in the class community were very important as all the members who were treated equally in KBE were responsible for knowledge contribution and construction. Moreover, as compared with the previous POP class/learning, students also demonstrated better English composition scores. The results implies that knowledge building pedagogy is useful for enhancing writing that requires idea diversification, thought clarification, structure completion, and community collaboration.

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Theorizing Learning Spaces: A Sociomaterial Approach

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Abstract: This poster session recognizes the expanding base of research in Future Learning Spaces and argues that one of the problems confronting this emerging area is the lack of robust analytical frameworks. Drawing from a sociomaterial perspective, we suggest Latour's (2005) Actor Network Theory (ANT) as a promising analytical lens. More particularly, ANT proposes the relationship in human-material interactions can be conceptualized as symmetrical, where the material is viewed as possessing an equivalent degree of agency. Building on this proposal we suggest network relations can be analyzed considering five material actors: (1) personal computing devices (e.g., bring-your-own-device); (2) furniture; (3) media displays; (4) Internet search engines; and (5) digital, cloud-based environments (e.g., Google Docs, online courses, etc.).

Keywords: sociomaterial, actor network theory, learning space, embodiment

Introduction

An increasing number of educational researchers and designers are pointing to the importance of learning spaces in the learning sciences (Charles & Whittaker, 2015; Kali et al., 2015). While much of the initial research has reported positive reception of these newly designed learning spaces (Scott-Webber, Branch, Bartholomew, & Nygaard, 2014), most of the empirical work has been framed in terms of how students and faculty perceive the physical or aesthetic attributes of the space rather than in terms of the relationship between the design of the space and learning theories (Boys, 2011). While students may tell us they find these spaces supportive and inviting, how do we theorize about the role of spaces in fostering and promoting learning? This paper sets out to offer a potentially productive theoretical framework informed by a sociomaterial perspective. We present this framework in relation to an open, and collaborative learning space on the campus of the Pennsylvania State University.

A sociomaterial approach

Sociomateriality urges greater recognition of the role of materials in shaping learning (Fenwick, Edwards, & Sawchuck, 2011). Van Note Chism (2006) asserts that material has been overlooked: "…we often fail to notice the ways in which space constrains or enhances what we intend to accomplish" (p. 2.3). A sociomaterial approach positions both the material (e.g., learning space) and the human (e.g., learner) on equivalent planes where both are capable of enacting change on the other, and thus possessing agency. Sociomateriality, however, only represents a starting point as it is not a framework *per se*, but rather serves as an umbrella for a group of approaches that call attention to the environment and non-human elements in a learning space. One sociomaterial approach for analyzing educational contexts is Actor Network Theory.

Actor Network Theory

Actor Network Theory (ANT) (Latour, 2005) conceptualizes networks as assembled by way of relational effects between material and non-material entities. ANT is particularly concerned with how these entities come together and are changed by their interaction. These change points represent nodes across a network of activity that weave together to form an assemblage. Assemblages figure importantly in ANT because they highlight how the human and material come together through a series of networked interactions.

For example, in educational contexts assemblages can appear as things such as a journal article or teaching standard. An important function of ANT is showing the sociomaterial processes or interactions that gave rise to an assemblage, that is, making visible the developing connections among the conversations, negotiations, materials, and so forth.

Within the context of a physical learning space, we propose the development of assemblages can be better understood by considering five types of material actors: (1) personal computing devices (e.g., bring-your-own-device or BYOD), (2) furniture, (3) media displays (e.g., class/group display screens), (4) Internet search engines, and (5) digital, cloud-based environments (e.g., Google Docs). In tracing the development of a learning space assemblage, the goal is to expand the view of interactions so the researcher not only sees how the learner

uses the material, but also how the material and its corresponding affordances shape the learner's perceptions, particularly in terms of the material's affordances.

ANT in the context of a learning space

We provide an example to further explain the sociomaterial approach outlined above. The Krause Innovation Studio on the campus of the Pennsylvania State University is an open, and collaborative learning space that provides learners with diverse arrangements of furniture and media displays to foster group discourse. The Studio has a built pedagogy, or architectural embodiment of learning theory (Monahan, 2002) focused on the following learning design principles: the inclusion of a diversity of spaces, support for BYOD, and technology-enabled furniture to support social practices (Rook, McDonald, & Choi, 2015). As an initial illustration of ANT applied to this type of space, we present data from a Learning Design Studio (LDS) course convened in the Krause Innovation Studio during the Fall 2015 semester. LDS featured authentic design scenarios where collaborative groups used a variety of tools to respond to learning design challenges. We use ANT to analyze the group design activity as an interweaving network of activity. This analytic perspective allows us to trace how different human and non-human actors within this network of activity assemble and exert force by influencing the nature and direction of the design conversation. Carefully tracing this activity over time provides the means for observing how some sociomaterial assemblages may assume more prominent visibility while others diminish. In the broader context of the field of learning sciences, we hope this analytical approach helps to shed light on whether space matters in learning and in doing so, we invite others to rethink their own research to uncover ways in which spaces serve as assemblages.

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Acknowledgments

Multi-Layered Online Workshop: Promoting Both Collaborative and Instructional Interactions at Medium Scale

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Abstract: A major challenge of learning and instruction in MOOCs is to create interactive environments that promote both collaborative and instructional interactions at scale. In this study, we propose a model of Multi-layered Online Workshop (MOW) in which learners engage in multiple forms of activities and the instructor team engages in assisting learners online synchronously. The present study describes the overview of our first design case.

Introduction

MOOC skeptics have criticized low completion rates in favor of lecture videos and texts in many courses by economic perspectives, whereas researchers have demonstrated unique aspects of MOOC registrants' behavior compared to school settings, and argued the need of reconceptualizing learning and instruction in MOOCs (DeBoer et al., 2014). Furthermore, learning scientists have critiqued the lack of cognitive and social scaffolding, yet arguing the need of design and research for creating interactive learning environments (Grover et al., 2013).

Rationale for promoting scaled collaborative and instructional interactions

Researchers have designed "group technologies" such as *talkabout* (https://talkabout.stanford.edu) that facilitates small group assignment for video chat, *Bazaar Collaborative Reflection* that has similar functionality for text chat facilitated by a computer agent, and *Quick Helper* that assists users in finding others who could potentially answer their question on the online forum (Ferschke et al., 2015). These group technologies would promote *collaborative interaction* among learners, while few studies have discussed *instructional interaction* in which the instructor (team) directly interacts with learners. We argue that it is important to promote both interactions, and develop theoretical models and related technologies to enhance learning experience in MOOCs. In line with this goal, we have demonstrated that a blended design combined with face-to-face sessions can develop historical reasoning (Oura et al., 2016). The remaining issue with this approach, however, is its limited scalability per session. To overcome this, we propose a model of multi-layered online activity design below.

Multi-layered online workshop model

A *Multi-layered Online Workshop* (MOW) in the online system *gaccatz* consists of a sequence of "whole," "group," and "room" modes or activities (see Figure 1: top left). The whole mode is a form of standard online broadcasting in which the instructor broadcasts his/her materials to each participant through video and slides (individuals can communicate in text chat). The group mode is for small-group activities with 3-4 individuals with each group working on a shared whiteboard through voice/text chat (no video) (top right). The room mode consists of 3-4 groups in which the group leaders present their discussion through voice chat (other members can comment only in text chat) (bottom left). Such multi-layered activity design with the system allows the instructor to engage learners in dynamic activities involving listening to guidance, working in small groups, and presenting and discussing with other groups. Moreover, teaching assistants (TAs) are available to assist learners online synchronously at medium scale up to hundreds of participants (bottom right).

To illustrate a specific design with the MOW model, we describe our first design case with its activity flow and online system as follows. This online workshop was conducted along with our history course on a Japanese MOOC platform "gacco" (http://gacco.org), and the main objective of the workshop was to develop an understanding of historical reasoning with old documents by verifying the sender and receiver, where/when it was written, and why the document(s) was written. A total of 135 individuals with diverse backgrounds participated in the trial event, and the instructor started by showing three pictures, and discussed various objects that could be historical evidence by analyzing them in the whole mode.

After the introduction, participants were randomly assigned to small groups for their introductory session in the group mode. Back to the whole mode, the instructor presented an old document without the sender information, and asked participants to think why it was written that way. Then, switching to the group mode again, they discussed the reason for 30 minutes (Figure 1: top right). After the group activity, in the room mode, randomly

assigned 3-4 groups shared their discussion and conclusions followed by voting each other for 15 minutes (bottom left). After the room activity, they went back to groups again to reflect on their discussion and the room activity for 10 minutes. Finally, back to the whole mode, the instructor summarized the online session ending with the nominated group leader's short summary of their work to the whole group. During the event, four TAs engaged in monitoring and assisting each whole/group/room activity as well as responding to twelve requests by the participants (bottom right). These demonstrate that MOW has a potential to engage participants in collaboration as well as allowing the instructor team to timely assist them when needed.
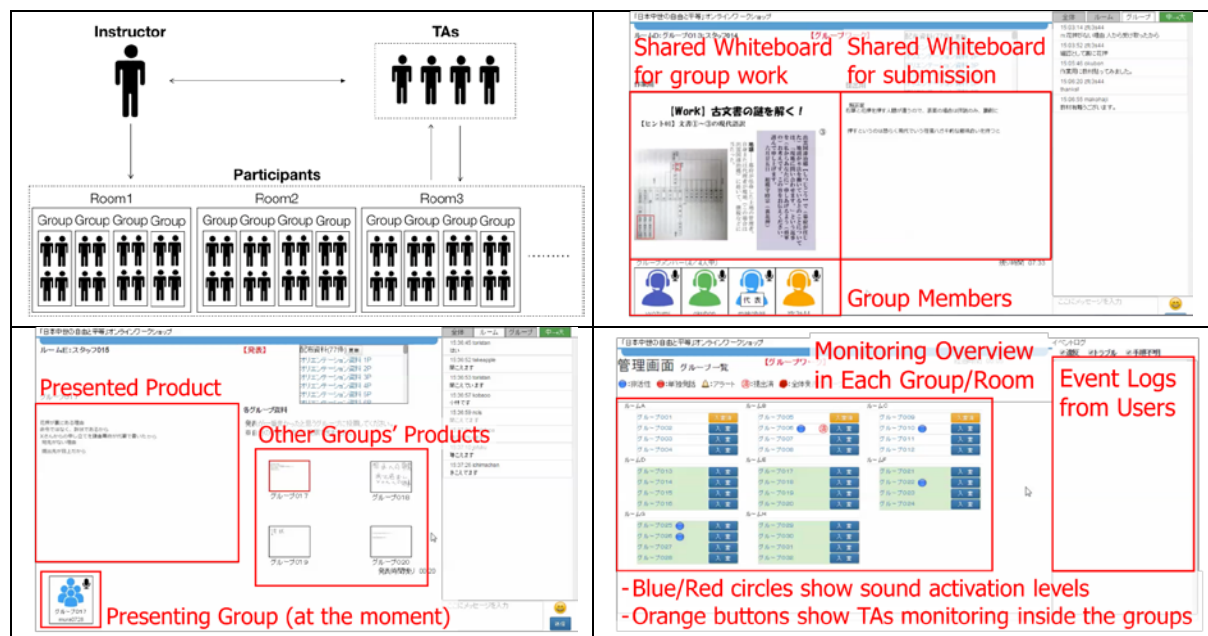
Figure 1. The Conceptual Model of MOW (top left) and Screenshots of its Online System (TAs' View).

Summary and future work
The present study proposed the Multi-layered Online Workshop model with the overview of our first design case, and our future work will include similar studies on a larger scale and developing the scaffolding theory.

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Acknowledgments

From Knowing to Doing: Increasing the Confidence of Communities to Take Action and Save Lives

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Abstract: Many of the victims from natural hazards are senior citizens. This poster examines the results of a learning environment/module designed to train participants (e.g., younger family members and friends) on the preparedness needs of seniors. Participants reported that they were more confident in their disaster preparedness knowledge after completing the module. Knowing what to do is not enough—one must have the confidence to act in order to save lives.

Introduction

Shifts in weather patterns caused by climate change have produced surprising and extreme impacts with hazard events such as Hurricanes Katrina in 2005 and Sandy in 2012 ranking as some of the deadliest events in recent history (Centers for Disease Control and Prevention, 2013; Gibson & Hayunga, 2006). The Indian Ocean Tsunami in 2004 and Japan Tsunami in 2011 were no different with seniors experiencing the highest mortality rates (Frankenberg, Gillespie, Preston, Sikoki, & Thomas, 2011; Nakahara & Ichikawa, 2013). Although hurricanes and tsunamis differ in predictability and lead times, the effect on seniors is the same—senior are disproportionately vulnerable to natural hazards (Wang & Yarnal, 2012). Understanding natural hazards as it pertains to preparedness is of paramount concern for seniors and their families.

Disaster preparedness is not an easy prospect for seniors. The economic, medical, social, cognitive, and physical hardships they experience may make it difficult for them to take the necessary actions to prepare for disasters. These hurdles have led to an increasing trend of seniors moving in and residing with their younger relatives. Consequently, training younger relatives and friends in disaster preparedness will enable them to make decisions that will help mitigate the impacts of hazards and save the lives of seniors.

Theoretical framework

Emergency management agencies have been working to address the needs of communities, but communicating information is only effective if residents also believe in the information (Basolo et al., 2008). Furthermore, Basolo et al. (2008) note that it's not enough to recognize the risks associated with natural hazards, communities must be able to act on that information. For example, tsunamis give little or no warning yet communities must still respond, with or without government action. Knowing is not enough—action must occur. Communities must 1) quickly determine if they are in a tsunami inundation zone, 2) evacuate immediately if necessary or remain where they are if not in danger, and 3) avoid the impact areas until an "all clear" is announced. Caregivers must be motivated to make decisions on behalf of their seniors and have confidence in their actions.

Training can also help those who do not plan ahead or who are more likely to give in to a fight-or-flight mentality or another physiological response. Training can enable participants to increase their metacognitive capabilities to adapt to various situations, avoid taking detrimental actions, curb fear, increase motivation, or prevent themselves from overcommitting time and resources—all of which can prevent caregivers from taking action (Pfeffer & Sutton, 2013; Yeung & Summerfield, 2012).

Module design

An online delivery format using Articulate Storyline 2 and Canvas was selected for the learning environment/module as it allowed for the use of dynamic videos, scenarios, knowledge checks, and tutorials to promote improved learning and retention (Deslauriers, Schelew, & Wieman, 2011; Mounsey & Reid, 2012). An online format also promoted open access to the information. The content presented was adapted from courses certified by the Federal Emergency Management Agency in order to maintain credibility as well as improve motivation, learning, and retention (Grossman & Salas, 2011).

The ARCS Model of Motivational Design and other instructional design techniques were used to capture attention, establish relevance, instill confidence, and provide satisfaction (Keller, 2010). These design decisions were done to help participants increase their knowledge while building their confidence to help senior citizens prepare for, respond to, and recover from natural hazards. The learning environment allowed participants to focus on improving both knowledge and confidence in tandem, allowing participants to gain a realistic view of what they were learning (Sundblad, Biel, & Gärling, 2009).

Methods

Adult learners (n = 35) with no formal training in senior caregiving or disaster preparedness participated in this study. The participants were from the United States and were college students or employees. Thirty-two participants reported that they had at least a two-year college degree while 28 reported that they were employed full-time. Twenty-four participants (69%) were under 40 years of age. Nearly half (46%) responded that they lived with or provided care for at least one senior. Instruments included surveys and a learning assessment. Participants accessed the online learning environment/module asynchronously over the span of two months.

Pre- and post-surveys were administered to participants asking them to report whether they agreed to statements that they were confident in their knowledge of disaster preparedness. A Likert scale was used for the questions (Strongly Disagree = 1, Disagree = 2, Unsure = 3, Agree = 4, Strongly Agree = 5) and the responses were analyzed using descriptive and inferential statistics.

Findings

Survey results indicate participants' confidence in their knowledge of disaster preparedness increased after completing the instructional content. The 35 participants had an average difference from pre- to post-survey confidence scores of 1.23 (SD = 0.97), indicating that the training resulted in a significant increase in participant confidence levels, $t(34) = 7.472$, $p < .001$ (one-tailed).

Conclusion

It is important to plan and prepare against the gradual rise of the frequency and intensity of natural hazards. Natural hazards are unpredictable and this uncertainty can make it difficult to follow set plans, resulting in decreased confidence and motivation. This project has shown that the design and use of a learning environment can be transformative and enabling, resulting in increased confidence.

Research on confidence and assertive decision-making should continue. Understanding this can help researchers determine the best approach to rapidly improve confidence in the event of a disaster, or develop methods to maintain individual confidence to challenge groupthink and conformity. Future iterations of this study should also follow-up with participants to maintain temporal reliability.

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Using Learning Performances to Design Science Assessments That Measure Knowledge-in-Use

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Abstract: New reforms in science education have ushered in fundamental changes in instruction and assessment. These changes include a focus on tightly integrating what students know with what they can do in science. We describe *learning performances* as integrated performance statements that help teachers identify formative assessment opportunities to support their students in achieving complex end-of-grade-band science performance expectations. This poster describes a principled approach for designing assessment tasks aligned with learning performances that can help guide teachers' instructional decisions.

Keywords: science, formative assessment, design, standards

Introduction

The U.S. Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) emphasize that science proficiency requires using and applying knowledge to make sense of phenomena and/or design solutions to problems (NRC, 2012). Central to this view is that disciplinary core ideas, science and engineering practices, and crosscutting concepts are tightly intertwined and work together to advance learning. Accordingly, assessment developers need guidance to design assessment tasks that integrate the three dimensions of the NGSS (Pellegrino et al., 2014). Our process addresses the need for classroom-ready assessments that teachers can use formatively to provide insights into students' progress toward achieving three-dimensional learning goals, referred to as performance expectations (PEs) in the NGSS.

Evidence-centered design and learning performances

To address the goal of formative assessment during the course of instruction, we use evidence-centered design (ECD) (Mislevy & Haertel, 2006) to systematically unpack performance expectations into multiple components that we call *learning performances,* which can guide formative assessment opportunities. Our learning performances constitute knowledge-in-use statements that incorporate aspects of disciplinary core ideas, science and engineering practices, and crosscutting concepts that students must integrate to achieve the larger end-of grade-band performance expectations. For classroom purposes, learning performances also identify formative assessment opportunities for teachers. Learning performances not only represent the content of the PEs, but also address intermediate instructional targets aligned with the PEs and potential student learning trajectories toward achieving the PEs. Our design process enables us to derive a set of learning performances from a PE in a principled way (described below), ensuring that the learning performances meet these requirements.

Design process overview

Here we provide an overview of our ECD process involving unpacking the three NGSS performance dimensions, developing integrated concept maps, articulating learning performances, and specifying design patterns for assessment tasks [Figure 1(a)].

Unpacking of performance dimensions

Our unpacking process entails gathering information about how knowledge and abilities are acquired and used in the domains for purposes of designing assessments. We unpack the disciplinary core ideas by elaborating key concepts, defining grade-band appropriate expectations for proficiency, defining assessment boundaries; and identifying background knowledge that students required for a complete understanding of a disciplinary core idea. We unpack the science and engineering practices by defining the core aspects of the practices, identifying intersections with other practices, and articulating the evidence required to demonstrate the proficiencies associated with the practice. We unpack the crosscutting concepts by defining their core aspects and articulating the evidence required to demonstrate proficiencies associated with the crosscutting concept.

Developing integrated concept maps

Based on the unpacking, we develop integrated concept maps that lay out the conceptual terrain for each PE. These integrated concept maps describe the essential disciplinary relationships and link them to aspects of the targeted crosscutting concepts and science and engineering practices. These maps are essential to the principled articulation of a set of learning performances that integrate the performance dimensions and coherently represent the target PEs. An example of an integrated concept map derived from two NGSS PEs on chemical reactions and properties of substances appears in Figure 1(b).
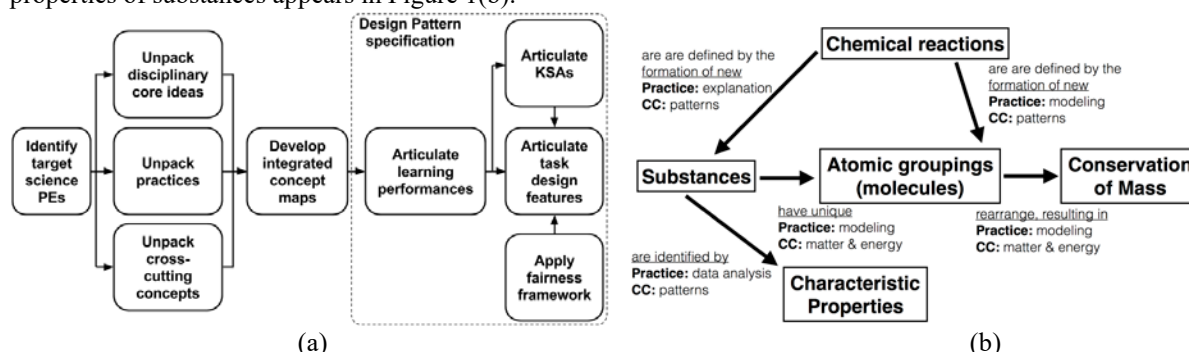
Figure 1. (a) Design process summary (b) Integrated concept map of NGSS PEs MS-PS1-2 and MS-PS1-5.

Articulating learning performances and specifying design patterns

We next articulate a set of learning performances and specify a design pattern for each one. Assessment designers can use design patterns to develop assessment tasks that are aligned with target proficiencies. The design patterns describe task features that are necessary to elicit evidence of student proficiency and include:

- **Articulating knowledge, skills, and abilities (KSAs).** For each learning performance, we articulate the focal KSAs representing the specific performance constructs that are to be assessed. We also identify additional KSAs that are needed to respond to the task but are not assessed by the task.

- **Articulating assessment task design features**. Design patterns describe two types of assessment task features that reliably elicit the focal KSAs: (1) *characteristic features*, which *must* be present to provide the desired evidence of proficiency, and (2) *variable features*, which may be varied in order to shift difficulty, focus or context, or to address the needs of students with specific instructional requirements or abilities.

- **Applying an equity and fairness framework**. Our design patterns include task features derived from the use of an equity and fairness framework that we developed to help ensure that tasks fairly assess students across social groups. This framework is based on Universal Design for Learning (e.g., Rose, Meyer, & Hitchcock, 2005), which was originally conceived to address the needs of students with disabilities.

Implications

Our design approach addresses challenges identified for next-generation science assessment design, particularly the complex domain definitions and student performances associated with three-dimensional science proficiency. ECD provides a principled approach for addressing these complexities in ways that can support the deep, integrated learning called for by new visions for science education.

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Effects of Knowledge Building Activities on Student' Writing Performance

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Abstract: The purpose of this study was to investigate the effects of knowledge building activities on fourth-grade students' writing performance. Data collected include the experimental and control groups' average writing test scores and the experimental group's online learning activities. The results showed that students in both of the experimental and the control group improved their writing performance. Moreover, The experimental group outperformed the control group significantly.

Keywords: Knowledge building, writing performance, Knowledge Forum

Introduction

Our information society is gradually transformed into a knowledge society where the value of knowledge creation and integration is emphasized. To create knowledge, it is essential for students to see themselves as knowledge workers and to reflect and refine what they know in order to keep up with this dynamically changing knowledge world. Under the circumstances, knowledge building (Scardamalia & Bereiter, 2006) is critical and defined as a collaborative process of sustained idea generation and improvement valuable to learning communities. It is based on the premise that ideas are improvable and that helping students to become idea/knowledge workers is essential to prepare them to enter tomorrow's workplace in the knowledge society. Previous studies using knowledge building have been conducted in elementary schools, but mainly in the subject area of science, math, and language. In this study, we specifically focused on reading and writing. In addition to helping students acquiring information/facts from their reading text, this study aimed to help fourth-grade students read by making good use of their own imagination and by generating their own ideas for deeper questioning/discussion and writing activities in Knowledge Forum (Scardamalia & Bereiter, 1994). This is very different from the traditional way of writing from which students were asked to reproduce information from textbooks without critical thinking and understanding. To address this issue, knowledge building approach was implemented to help students learn to produce and improve their ideas by engaging in collaborative discussion for improving their writing ideas (Scardamalia & Bereiter, 2005). Previous studies also indicate that critical or ideational writing can help deepen one's higher-order thinking.

Methods

This study adopted a quasi-experimental design. There were 25 and 28 fourth-grade students in the experimental and control group, respectively. The experimental group participated in 18-week knowledge building and sustained ideational writing activities in order to enhance their writing performances. Students in this group were supported to build a learning community where generation and improvement of writing ideas were appreciated and implemented collaboratively in the class. Knowledge Forum (KF) (Scardamalia, 2004) was used to provide a computer-support online environment where participants can contribute ideas, make plans, search for ideas/facts/words/evidence, identify reference materials, and so forth in this virtually shared place (Scardamalia, 2004). In contrast, the control group was taught in traditional instructional environment where teachers taught the textbook content directly and asked students to practice writing based on what they has read from textbook (i.e., teacher-directed instruction).

Essay writing tests were used to assess children's writing performance. To this end, teachers gave both groups the same writing topics, one at the first week and one at the last week, as pre-test and post-test. In order to evaluate the quality of students' writing, a four-dimensional scale was developed based on a validated writing quality scale (Research Center for Psychological and Educational Testing, 2014). The four dimensions selected for quality assessment were: coherence, organizational structure, readability, and level of mandarin literacy.

Quantitative data includes: (1) pre- and post- essay writing, (2) pre- and post- PIRLS (Progress in International Reading Literacy Study) reading comprehension test, and (3) students' online activities in KF. Qualitative data came from interviews with both of the experimental and the control groups in order to understand how students changed their ideas and whether students improved their idea generation and reading comprehension.

Findings

The results of an independent sample t-test showed that the experimental group's pre-post gain (M=4.48, SD=0.87) outperformed that of the control group (M=3.79, SD=0.73) (t= 3.14, p<.01). These results suggest that the experimental treatment did have a positive effect on students' writing performance. In addition, a dependent sample t-test was conducted to compare experimental group's online activities in Knowledge Forum in the first 9 weeks and the other 9 weeks (using mid-term as a separation point). As Table 1 shows, indicators of students' online activities significantly increased in the experimental group. The indicators include notes saved, notes read, and build-on ideas created. The results further revealed a significant positive relationship between writing test scores and student's online activities (see Table 2).

Table 1. Students activity in Knowledge Forum

activity	weeks1-9		week10-18		
	M	SD	M	SD	t-test
Notes saved	9.1	4.19	15.7	5.63	-6.76*
Notes read	75.4	39.56	114.2	57.33	-4.44 ***
Builds-on created	4.3	2.58	10.2	4.97	-7.6**

*p< .05, ** p< .01, *** p< .001

Table 2. Correlations between writing scores and student's activities online

Measure	1	2	3
1.Post writing scores	1		
2.Notes saved	.4*	1	
3.Notes read	.31	.43*	1
4.Builds-on created	.45*	.97***	.44*

*p< .05, ** p< .01, *** p< .001

Moreover, an independent-sample t-test was conducted to compare gains in PIRLS test scores between the experimental and the control groups. After 18 weeks of participating in knowledge building activities, the experimental group demonstrated significant more improvement in the test score (M=26.28, SD=3.87) than the control group did (M=23.07, SD=3.13) (t= 3.33, p<.01). The results suggested that the experimental treatment did have a positive effect on students' PIRLS reading comprehension achievement. In addition, the interview data also showed that knowledge building have positive influence on the experimental group, especially on students' collective responsibility to create new ideas. As for students' understanding of ideas as improvable objects, the experimental group also showed better understanding, whereas the control group didn't show such kind of change.

Conclusions and implications

In this study, we investigated the effects of knowledge-building pedagogy on students' writing performance. Knowledge building supported the development of a collaborative and constructive learning community that guides students to work and improve their reading/writing ideas. The online platform, Knowledge Forum, also provided a virtual place where student could construct/share/disseminate/reflect/improve their ideas. From a knowledge building perspective, writing is not merely a product, but more importantly, represents an evolving and emerging process of understanding. By means of a knowledge-building process, students worked on ideas, received feedback for improvement, and enhanced their writing skills. As students really cared about their ideas they were working on, they were more likely to improve their writing skills and interpretation of each other's work. In this way, they demonstrated characteristics of an active knowledge worker.

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Communicating Culture: Building a Network of Participatory Teacher Meetups to Support K–12 Computing Education

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Abstract: Scratch educator meetups are participatory professional learning experiences for K–12 teachers working with the Scratch computer programming environment. These gatherings have created demand for meetups in communities around the world. Adopting the lens of network structures, we are currently studying the implementation of Scratch educator meetups in new geographic locations to inform a larger dissemination strategy.

Keywords: computing education, teacher PD, participatory learning, ScratchEd, model dissemination

The importance of teachers in computing education

Modern life is increasingly saturated with and structured by computers and computation. As such, the development of computational literacy—learning to use computation for self-expression and problem solving by learning how to program—offers enormous economic and personal power (Kafai & Burke, 2014; National Research Council, 2010). Despite this potential, most young learners interact with computers and computation primarily as consumers—watching music videos, playing games, or posting personal updates—rather than engaging with computation as producers, creators, or designers. This problem is due in no small part to a lack of equitable access to K–12 computing education opportunities (Cooper, Grover, Guzdial, & Simon, 2014). Because the vast majority of young learners do not have access to computing education in school, computational literacy is too often reserved for those from privileged home environments.

Teachers can play a critical role in disrupting this inequity and democratizing access to computing education—creating classroom cultures that support computational literacy and that offer all students opportunities for computational creation (Brennan, 2013). Teachers have the potential to reach students who do not enjoy the "preparatory privilege" of affluent home environments or extra-curricular camps and programs (Ryoo, Margolis, Lee, Sandoval, & Goode, 2013). Teachers can also provide much-needed cognitive scaffolding to novice programmers, offering support to young learners as they engage the computational concepts and problem-solving strategies necessary to develop as a programmer (Robins, Rountree, & Rountree, 2003). The goal of our work is to expand notions of literacy and to support coding as part of K–12 students' expressive repertoires—and to engage teachers as central contributors to this learning and development.

A participatory approach to teacher learning

Despite the importance of teachers for supporting equitable access to computing education, very little is known about how to support K–12 educators as they endeavor to include computing as part of their pedagogical design activities. In response, we have been designing and studying a model of professional development that supports teacher thinking and action in the service of computing activities in the classroom, particularly for teachers working with the Scratch programming language. This research and development initiative, named ScratchEd, includes various forms of support for teachers, including curriculum and an online community (Brennan, 2015). An important component of the ScratchEd work has been hosting meetups, which are in-person, participatory learning experiences for educators. ScratchEd meetups, which are designed and facilitated by teachers, are opportunities to engage in the kinds of designing, personalizing, sharing, and reflecting activities that will ideally be made available to students (Brennan, 2012). The participatory approach to the design of meetups has been informed by previous scholarship on communities of practice, literature on teacher professional development, and constructionist theories of learning—which frame learning as a process of increasingly sophisticated participation through interactions with others (Papert, 1980; Grossman, Wineburg & Woolworth, 2001; Lave, 1991; Rogoff, 1994).

Building a network

Hundreds of teachers have participated in the Boston, Massachusetts meetups since they began in 2010. Although ScratchEd meetups organized in the Boston area have catalyzed a flourishing local community of practice, face-to-face gatherings are geographically limited. There is interest beyond Boston, as demonstrated by email requests,

ScratchEd online community postings, and educators from around the United States traveling (sometimes at significant distance and cost) to attend events. Given that educator interest has outpaced our research team's ability to meet demand, we are currently exploring the development of ScratchEd meetups beyond the Boston area. Lessons gleaned from literature on nonprofit strategy (Wei-Skillern, 2008) have suggested a promising way forward. Adopting a networked approach, whereby the services and resources provided by a central hub (our team at the Harvard Graduate School of Education) are combined with node partners in other locations, we are currently studying the early implementation of meetups in Washington, D.C.; Lexington, KY; New York City, NY; New Orleans, LA; and San Francisco, CA. The network is being built through *modeling-scaffolding-fading*, with the hub team hosting one or more initial meetups in a city, recruiting hosting partners who are based in the city to continue hosting over time, and gradually transitioning hosting responsibilities to the partners, offering support as needed, including connections across cities.

By examining implementation efforts in other geographic locations using a case study approach (Yin, 2009), we are developing more nuanced understandings of how the ScratchEd meetups model is adopted and adapted in new contexts, and how the model's constructionist sensibilities are communicated and enacted from site to site. Data collection includes: journaling by the hub team, communication between the hub and nodes, interviews with organizers, and meetup observation data. Our analysis is focused on: (1) factors that contribute to or inhibit the adoption of the model in a new geographic location, and (2) elements of the model that can and/or should be adapted to suit local contexts vs. elements of the model that should remain invariant. By leveraging case study findings to inform a plan for disseminating the meetup model, we hope to enrich teacher professional development and promote distributed expertise throughout the ScratchEd community of practice, making powerful computing education experiences accessible to all K–12 learners.

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Acknowledgments

Do Collaborative Learning Elements in Online Courses Improve Conceptual Knowledge Acquisition?

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Abstract: Implementing small group collaborative learning in online courses effectively is a major challenge. Theoretical reflections suggest that one of the factors influencing the success of collaborative learning is the type of knowledge that is targeted by instructional materials: Concept-oriented materials could be particularly suitable for learning collaboratively. In two experimental studies we investigated the effects of learning mode (collaborative vs. individual) on learning outcomes in an online-learning environment focusing on conceptual instructional material.

Keywords: collaborative learning, conceptual knowledge, online learning, MOOCs

Introduction

Research on collaboration in large online courses provides evidence for the potential of social interaction in small group discussions to improve learning outcomes (e.g. Rosé, Goldman, Zoltners, Scherer & Resnick, 2015). However, designing effective small group collaborations - not only in online courses - is a major challenge. Theoretical reflections of research on knowledge acquisition (e.g. Rittle-Johnson, Siegler & Alibali 2001) and collaborative learning (e.g. Herrmann & Kienle 2008; Chi, 2009) suggest that one of the factors influencing the effectiveness of collaborative learning is the type of knowledge targeted by instructional materials. Conceptual knowledge is promoted by explorative learning activities and self-explanation (e.g. Chi, Bassok, Lewis, Reimann & Glaser, 1989). In collaborative learning settings, learners are encouraged to verbalize their knowledge gaps, to discuss different points of view (Herrmann & Kienle 2008), to engage in mutual elaboration, and thus to jointly extend their knowledge (Chi, 2009). Therefore, collaborative learning elements seem particularly suitable for the acquisition of conceptual knowledge. Findings by Mullins, Rummel, and Spada (2011) corroborate this assumption. Against this background we hypothesized that tasks or activities a) requiring discursive and elaborative activities and b) targeting construction of conceptual knowledge lead to more learning in a collaborative learning mode than in an individual learning mode. Our hypothesis is examined in two consecutive experimental studies. Methods and results of the first study are reported below. Data collection for the second study is still in progress at the time of this writing. As technical and methodological problems occurred during the first study, the results of the second study will be important to test our hypothesis once again with more rigorous experimental control.

Methods

To test the effects of learning mode on conceptual knowledge construction in an online course ("Psychological principles of computer-mediated communication"), course participants completed one individual and one collaborative task in a sequential experiment (see figure 1). Knowledge tests in form of an open ended question measured students' learning gain.
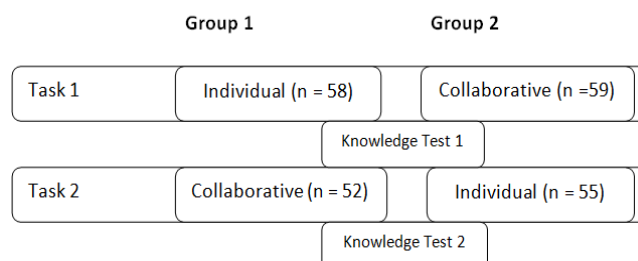
Figure 1. Course design and number of participants in the conditions for every course unit.

Results

Scores in the knowledge tests for tasks 1 and 2 were not normally distributed for the overall sample. Therefore, we ran separate Mann-Whitney U tests to investigate differential learning outcomes between the individual and

cooperative learning mode (see Table 1).. However, the differences between the two conditions were not statistically significant (Task 1: $U = -.061$, $p = .952$; Task 2: $U = -.726$, $p = .468$).

Table 1: Scores on the knowledge test by task and learning mode

	Task 1 (max: 6)						Task 2 (max: 8)					
	M	*SD*	*Min*	*Max*	*N*	*dropout*	*M*	*SD*	*Min*	*Max*	*N*	*dropout*
Individual	4.64	1.35	2	6	58	6	3.86	1.59	0	8	55	5
Collaborative	4.63	1.37	2	6	59	14	4.09	1.54	1	8	52	5

Discussion

Contrary to our hypothesis we did not find statistically significant differences in the learning outcomes between individual and collaborative learning mode in our first study. This contradicts previous findings demonstrating a benefit of collaboration for various learning outcomes in face-to-face settings. The null result of the present study suggests that this benefit might not generalize to online learning environments. Differences in communication between online and face-to-face settings in particular, e.g. regarding simultaneity or cotemporality, might account for the finding that small group collaboration did not improve conceptual knowledge gain over the individual learning mode.

However, we also consider that the potential of small group collaborative online learning might not have been fully tapped for various reasons. *First*, as it is typical for online courses, overall group work activity was rather low (33-48% groups with one or more inactive group members) which might have lead groups with an insufficient number of active participants to fail completing the task, or, in case all but one members were inactive, to an individual task completion. To reduce the amount of inactive group members and increase commitment and individual accountability in Study 2, explicit participation confirmation by all course takers previous to the assignment will be required. *Second,* most of the participants were not used to work in online courses. As a result, some of them did not check for announcements or emails regularly. This led to confusion with respect to current tasks, and students frequently missed deadlines. For Study 2, students will be constantly prompted with upcoming deadlines to increase assignment compliance. *Third,* from research on collaborative learning, we know that small group collaboration does not work well without proper support (e.g. Slavin, 1996). At the same time, providing this support would have introduced a confound between individual and collaborative learning in our experimental design. Hence, we kept the cooperative and individual condition the same regarding task support. This prevented us from taking full advantage of the possibilities to support small group work.

The currently running follow-up study provides an opportunity to test our hypothesis again with a substantially improved methodology. In Study 2, we will take in to account the identified problems and deploy the above stated improvements and solutions. The results of both Study 1 and Study 2 will be presented at the conference.

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"That's What Teachers Do!" "—Not <u>This</u> Teacher": Tensions in Reform Science Classrooms

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Abstract: As science classrooms are reformed to involve learners in science practices, these new classroom interactions require dramatic shifts for many science classrooms. This shift in classroom norms requires students to shift their understanding of the goals of their work and their roles in building knowledge. It is critical to understand the tensions that emerge for students as they adjust to this new environment in order to better support this transformation.

Keywords: classroom norms, science practices, collaborative knowledge building

Introduction

Current reforms in science education have focused on creating classroom environments in which students use science practices to construct explanations of phenomena in order to better build and use core science ideas (NRC, 2012). Creating such classroom environments requires a shift from positioning students as passive recipients of facts to positioning them as active, agentive constructors of knowledge (Berland et al., 2015). This is in stark contrast to traditional science classrooms that position the teacher as the authoritative source of all knowledge and focus on what students need to know as opposed to what they need to be able to do (Duschl, 2008; Stroupe, 2014). This shift impacts the discourse in the classroom as teachers begin pushing for student sense making rather than correct answers (Barton & Tan, 2010). Even when teachers try and adopt these approaches, students must also shift their understanding of classroom norms and roles in order to engage in this new type of classroom environment. How are students making these shifts and what does this transition in student understanding look like? How does students' understanding of classroom norms impact their understanding of their teacher's pedagogical choices? This poster investigates these questions by examining some of the tensions that emerge as students transition from traditional to more reform-based environments.

Methods and analysis

To investigate this question, we are analyzing classroom interactions using video data collected as a part of a larger longitudinal study. Video data were collected from a K-8 school ("Mountain View") in an urban suburb where students are largely white (50%), Asian/Middle Eastern (20%) and Hispanic (20%), and most are second-generation immigrants. The 6th-8th grade science teachers at Mountain View have a decade-long partnership with Northwestern University exploring how to support science practices in classrooms. The focal 7th grade teacher ("Mrs. K") for this study is using the curriculum materials that were developed through this partnership (IQWST; Krajcik et al., 2008). From the entire 7th grade science curriculum, 11 lessons were recorded because they were likely to provide high potential for eliciting evidence of student engagement in science practices. In each video, researchers identified episodes where students engaged in practices of argumentation, explanation, and modeling as these practices represent the more dramatic shift away from students being provided fully formed explanations. We analyzed these episodes to examine if any tensions emerged between the design of the activity and how the students engaged in the activity.

Findings

Throughout the 11 lessons, there was an abundance of evidence of students engaging with scientific practices as they worked with science ideas. Student-student talk increased and students were generally willing to present their ideas for their classmates before knowing the "correct answer." However there were a number of episodes that seemed surprising considering the progress the class was making. The following are two scenarios in which tensions, evident from classroom discourse, arose between traditional and knowledge-building instruction.

Prompts not critiques

In order to support student knowledge building through science practices, teachers work to prompt students to provide evidence for their positions and to expand and clarify their reasoning. These prompts can be effective in facilitating productive discussion in which together students build on individual ideas to refine them and reach consensus (Michaels & O'Connor, 2012). However, experience in traditional classrooms might lead some students

to interpret these prompts as flagging incorrect answers. This can be seen in classroom discourse during an exchange that occurred when Mrs. K asks a student ("Serena") for evidence for her idea and Serena answers, "It's similar" Mrs. K inquires, "It's similar?" and Serena responds, "Never mind!" When Mrs. K asks, "Why never mind?" and Serena answers, "Because you said I was wrong!" Mrs. K responds, "I didn't say that! Did anyone hear me say [that]?" and the whole class shouts "yes!" Mrs. K then asks Serena, "You felt like that's what that meant?" and Serena informs Mrs. K "That's what teachers do!" In response, Mrs. K replies "Not *this* teacher!" It is clear that some students see Mrs. K differently than she intends to be perceived. Despite months of being in a classroom where the teacher explicitly spoke about providing evidence in class discussions and that most of the students were in an inquiry-based science classroom the previous year, the students appear still influenced by their experience of traditional roles that teachers play in the classroom, interpreting the teachers' prompts to dig deeper into students' reasoning as evidence that the teacher thinks the students are incorrect.

Uncertainty in learning

In traditional classrooms in which teachers present explanations to students, uncertainty indicates students' lack of understanding. In contrast, argumentation and explanation require students to share partial explanations and be pushed on ideas through ongoing questioning. An example this tension can be seen in an exchange where a group of three students are presenting a model attempting to explain why a pendulum slows down over time. As part of the presentation, Alex explains that his group's model contains more air molecules after the pendulum has swung. Mrs. K asks, "So more molecules after, can you guys explain that?" The other two group member look at each other and giggle nervously and Alex mumbles an unintelligible answer, all of them unsure of how to proceed. Mrs. K goes up to their poster and tries to elicit more information from the group and then again asks, "But you're not really sure why you have more molecules in the picture?" The group hesitates and glances around again and Mrs. K says, "That's okay!" reassuring them that their uncertainty is permissible. Mrs. K was attempting to prompt her students to give her an explanation of their reasoning and "We still need to figure that out" was a perfectly acceptable answer. However, these students clearly felt uncomfortable in this situation. For them, "I don't know" and displaying uncertainty seemed an uncomfortable option despite reassurances.

Conclusions and implications

As researchers and practitioners work to increase the role of science practices in K-12 classrooms, it is critical to not only think about the challenges teachers might face in reforming their views of the science classroom but to also consider the challenges students might grapple with in adjusting to this new learning environment. Mrs. K worked hard and in many ways successfully facilitated the transition to a reform classroom, making science practices the way students did science work, yet her students still had moments where they pushed back. These episodes suggest that teachers cannot just inform students of the new classroom norms; students' epistemic beliefs must also shift.

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Acknowledgments

Affordances and Challenges of Using K-12 Classrooms to Support Preservice Teachers' Learning to Teach Climate Change

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Abstract: This study aims to analyze the ways to use K-12 teachers' experiences in improving the quality of climate literacy workshops for preservice teachers. Using the multiple-case method, we worked with eight inservice and seven preservice teachers. The data come from surveys, K-12 classroom written artifacts, and video recording of workshops. The preliminary showed many affordances as well as a challenge to using K-12 teachers' experience in preservice teachers learning to teach climate literacy.

Keywords: CHAT, teacher education, climate literacy, discourse

Humanity is the major influence on the global climate change observed over the past 50 years. Rapid societal responses can significantly lessen negative outcomes. (AGU, Adopted 2003, revised and reaffirmed 2007, 2012, 2013).

Introduction

Teachers might have an important role in decreasing the negative outcomes of climate change problems. This study focuses on developing sustainable climate literacy professional development (PD) for preservice science teachers. Although there are a number of hypothetical and empirical research studies on what and how K-12 students should learn about climate science (e.g., Shepardson et al., 2012), there remains a dearth of studies on teachers' understanding of climate science. Drawing from the socio-cultural theories of learning, this study is designed around the central question, *How do the K-12 classroom practices of teaching climate change facilitate a sustainable PD for preservice teachers?* Our study uses Engestroms' third generation of activity theory. This theory stems from the studies of Vygotsky, using mediating artifacts (e.g. language and educative materials) to scaffold subjects move towards their goals. This theory was renamed CHAT (Cultural-Historical Activity Theory) and the following dimensions were used to explain the triadic relationship in a community of practice: subjects, mediating artifacts (tools), rules, division of labor, and community (Engestrom, 1987). Engestrom later suggested the third generation of CHAT, focusing on the boundaries and transitions at intersections with the objects of the two related activity systems (Engestrom, 2008). The current study uses this framework to determine boundaries (shared object, common and distinctive features) between K-12 and preservice teacher communities of practices (Figure 1). Describing the two communities of practices will allow us transfer what we have learned from K-12 practice to preservice teacher education.

Methods

The study uses a multiple-case method (Yin, 1984) where the same climate change activity is implemented in eight different secondary school science classrooms. A daylong workshop was conducted for inservice teachers. After these eight inservice teachers implemented climate change lessons in their classrooms, they either provided resources or worked with seven preservice teachers who were recruited from methods courses at Towson, Delaware State Universities, and University of Delaware. Scientists and science educators also facilitated the collaborations between preservice and inservice teachers.

Analysis

To describe communities of practice, participants completed a survey on climate science content/practices and their perspectives to include climate change in their curriculum. This data is analyzed using descriptive statistics and the CHAT analytical framework (Figure 1). A second set of data came from the K-12 classroom practices. eight teachers submitted students' written artifacts and their own reflections on the implementation of the activity. A third set of data was from dialogic interactions between inservice and preservice teachers during professional development activities. Currently, we are working on discourse analysis to analyze the third set of data.

Findings

The preliminary analysis of this data showed how we can utilize our lessons from K-12 classrooms to develop PD for preservice teachers: (a) activities where preservice teachers evaluate students' naive ideas and explain how

they can improve their ideas into scientifically accurate explanations (b) using argumentative discourse as a cohesive practice to teach climate change through scientific practices (c) highlighting the interdisciplinary aspects of climate change. However, we also observe that unique challenges of inserveice teachers' school culture might limit the ambitious ideas preservice teachers have.
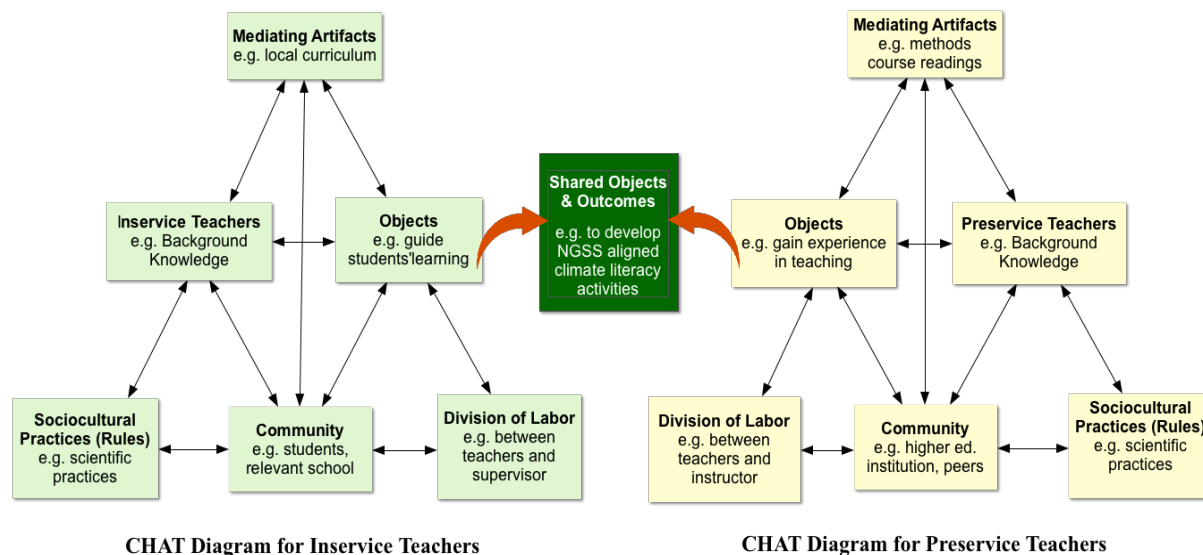
Figure 1. Cultural-Historical Activity Theory (CHAT) Analysis of Communities of Practice.

Conclusions and implications

Studies show that preservice teachers have a hard time transitioning from a university setting to a teaching environment with regard to reform minded teaching (Bransford & Stein, 1993). This study aims to equip preservice teachers with authentic classroom experiences within the boundaries of their community of practice. This study also exemplifies using CHAT as an analytic framework to describe the sociocultural dimensions of communities of practice.

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Acknowledgments

Finding Patterns in and Refining Characterizations of Students' Epistemic Cognition: A Computational Approach

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Abstract: Epistemic cognition has become an area of interest among education researchers. However, characterizing epistemic elements of cognition is difficult. Using computational approaches can contribute to conceptualizing and operationalizing what we mean by epistemic cognition. We present how we used two computational methods to see new dimensions of epistemic elements in students' written work. Our work demonstrates how computational tools refine our understanding of, and tools to examine, dimensions of epistemic cognition.

Introduction

Epistemic cognition has increasingly become an area of interest among education researchers, particularly in understanding and supporting student's use of epistemic criteria for building knowledge (e.g., Chinn, Buckland, & Samarapungavan, 2011). However, characterizing epistemic elements of cognition is difficult. Computational approaches to data analysis have been applied for educational data mining and learning analytics, but are not yet commonly used as a part of Learning Sciences research. To explore the use of such methods for characterizing elements of epistemic cognition, we present a combination of approaches for identifying students' epistemic ideas. To do so, we build on Sherin's (2013) and others' (i.e., Beggrow, Ha, Nehm, Pearl, & Boone, 2013) arguments for the use of computational methods as a compliment to traditional qualitative methods. First, we present our use of two natural language processing approaches to analyze students' written work about their modeling and explanation-building tasks embedded within the curriculum ("embedded assessments"). We demonstrate how using these methods provides conceptual benefits: they help us identify gaps in our coding scheme and refine our conceptual models of students' epistemic cognition. We present this work-in-progress as a contribution to the ongoing conversation around learning analytics in Learning Sciences research.

Method

In order to analyze the epistemic criteria that students used to build ideas, we collected embedded assessments designed to elicit students' consideration of the *Generality* of their diagrammatic models or written explanations constructed as a regular part of their science classroom activities. We asked whether their model or explanation should explain phenomena in general (e.g., a general way that chemical reactions occur) or just the specific situation on which they focused (e.g., how and why aluminum and copper chloride react), and why. We selected this criterion for our initial computational analyses because we had a relatively complete set of hand-coded student responses from a 7th grade chemistry unit ($n = 178$). We adapted our initial coding scheme (Table 1) to differentiate between responses that discussed the rationale for a general or specific account without (1) and with (2) a rationale, and those that addressed both general and specific elements and/or trade-offs (4a and 5). Over time, increasing scores would indicate that students are developing an understanding that scientific work involves building general principles from specific phenomena (Godfrey-Smith, 2003).

Table 1: Original Coding Scheme for Generality

Code	Description	Sample Response(s)
0	Unclear/not codeable	Because the cemig rauted (101466)
1	One level: No rationale	"Because that's the whole point of the model" (101309)
2	One level: Rationale	"That can explain the atoms [rearrangement] better" (101536)
4a	Level-crossing	"This should help with all open systems in general because we know that if this happens with other reactants, the atoms would still leave in an open system" (104148)
5	Level-crossing: Boundary conditions of Gen and/or Spec	"Because the question is asking about only 1 specific thing and if I talked about all the chemical reactions in general it would not make sense because in different chemical reactions different things happen, like bubble, smell" (101323)

We then used two natural language processing approaches that take advantage of patterns in relative frequencies and arrangements of words in a set of documents. First, we used a supervised (and therefore requiring hand-coded

data) approach to "train" a Naive Bayes classifier on the initial coding scheme. This was moderately successful but not convincing enough to use more widely. Next, we used an unsupervised or inductive approach that converts the text into vectors and groups them using centroid clustering (see Sherin, 2013). We reasoned that this approach would help identify patterns similar to those that a trained classifier would be likely to identify, which could then give us some leverage in "training" an automated classifier in the future.

Findings and discussion

Here, we compare the clusters of student responses to our assignment of our original codes to illustrate how this analysis is leading us to revise our coding scheme and eventually improve on our earlier supervised approach. For the 178 responses we analyzed, we found that a 9-cluster solution balanced interpretability and concerns of parsimony. We graphed the clustered responses by their manual code according to their new cluster (Figure 1). We found that some of these clusters corresponded to levels of the coding scheme. For example, most of the responses that clustered into the "Similarities and Comparisons Across Processes and Classes" topic, which had been hand-coded as either a 4a or a 5, which is conceptually similar.
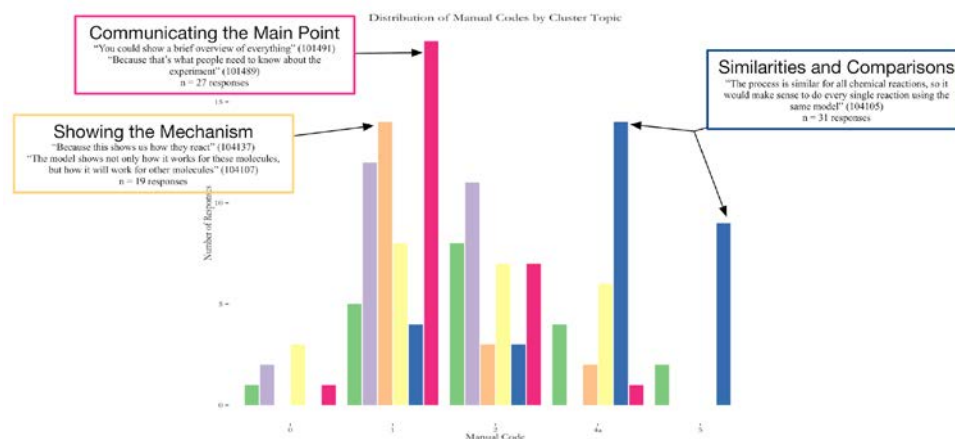
Figure 1. Distribution of Manual Codes by Cluster Topic.

In contrast, other responses did not correspond between manual code and cluster. For example, responses that we coded manually as 1 are the main responses in the clusters with the topics "Communicating the Main Point" and "Showing the Mechanism." The responses in these clusters differ as well: while both groups provide a rationale related to the intent of communicating some information, the rationales from students who communicated the main point are agnostic towards the substance of the main point, while rationales from students who show the mechanism focus on the importance of communicating mechanistic processes. This subtle difference may have important implications for how students' thinking about *Generality* develops.

These examples illustrate how computational methods may serve as tools to refine our coding scheme (and underlying conceptual models) as well as enhance the reliability of our analysis. Our moderately successful work with automated classification indicated that our initial coding scheme was not yet tailored to capture the patterns in our data. In addition, considering how the computer inductively clustered responses helps us to improve the already-coded data to train and use to a classifier. As computational tools become more widely used, we see great potential for them to support researchers' efforts to understand and develop ill-defined or difficult to capture constructs.

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Algorithmic, Conceptual, and Physical Thinking: A Framework for Understanding Student Difficulties in Quantum Mechanics

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Abstract: Quantum mechanics is notoriously difficult for students to understand. We observe groups of students solving quantum mechanics problems in upper-division physics. We use epistemological framing to understand students' problem solving, focusing on three frames: algorithmic math, conceptual math, and physical systems. We discuss the characteristics of each frame as well as causes for transitions between different frames. Instructors can facilitate students' shifts between the frames in order to fruitfully solve problems.

Keywords: mathematics, physics, quantum mechanics, epistemological framing

Introduction

As the language of physics, mathematics is critical to the understanding of quantum mechanics. Students generally have enough understanding of mathematics to solve introductory quantum mechanics problems, but in practice they frequently have considerable difficulty applying that understanding appropriately. Unsurprisingly, students often have trouble unifying these ideas for productive problem solving. Researchers in student understanding of quantum mechanics have used a "difficulties" framework to understand student reasoning (e.g. Singh and Marshman, 2015), but we believe that these disparate difficulties can be unified through examining students' epistemological framing (Tannen, 1993) and errors in frame transitions (Irving et al, 2013).

Epistemological frames (e-frames) govern which ideas students link together and utilize to solve problems. Productive problem solving requires both an appropriate frame (e.g. Scherr and Hammer's (2009) discussion frame) and appropriate transitions between frames. Instructors can nudge students into different frames (Irving et al, 2013), so it is important to observe instructor behavior as well as students. Previous research (Bing et al, 2012) identified four e-frames to investigate the role of math in physics; however, they didn't differentiate between conceptual math and algorithmic math. An efficient problem solving process not only requires physical sense making and algorithmic manipulations, but also conceptual thinking about mathematical representations and coordination between math and physics ideas. We investigate three frames: *algorithmic math*, *conceptual math*, and *physical systems*, looking for moments where students' problem solving is impeded because they are in an unproductive frame.

Methods

We collected video data from one semester of a senior-level undergraduate quantum mechanics course. The class was a mixture of traditional lecture and spontaneous bursts of in-class problem solving where students worked in groups of 2-3. We collected video data of students' whiteboards for three different groups throughout the semester. The instructor controlled the length of each problem solving interlude, generally 2-5 minutes.

To analyze an episode, we closely examined students' discourse and whiteboard writing as they worked on a problem, which provided cues for determining students' frames. Table 1 characterizes the three frames of interest based on analysis of students' actions, skills, and approaches associated with each frame. Two independent raters came to consensus on every episode; two additional raters checked a selection of episodes with >90% agreement. Once we found students' frames, we looked for shifts in frames to help us to interpret the dynamic of students' problem solving behaviors.

Example and analysis

In the previous class session students discussed that the probability density of a stationary state is time independent. In this session the instructor asks the students to find if the probability density of a superposition of two stationary states ($\Psi 1$ & $\Psi 2$) is time dependent or independent. The solution involves including the time dependent phase factors for each term in the wave function, then multiplying the wave function by its complex conjugate. The time dependent parts in the cross terms persist, meaning the probability density is overall time dependent, even though the probability density for each state independently is not time dependent. One student explicitly discusses his (incorrect) reasoning, displaying a very common difficulty:

Student: I think—'Cause when you do the, um, absolute value, you have to multiply by the conjugate, so I'm pretty sure that e thing (exponential function) will just go to one, 'cause with… that e to the minus blah blah blah with e to the plus blah blah blah, and then when you multiply them…1 over, you know, x over x. That's what I'm thinking.

The student is in the conceptual math frame because he reasons from the behavior of the product of an exponential function and its complex conjugate to determine his answer.

After about two minutes the instructor asks if the answer is time dependent or independent. The student replies that it is time independent. The instructor reveals that it is time dependent, and the student replies "It is time dependent? Why?" The student falls silent as he performs algorithmic calculations to answer his own question, suddenly (and dramatically) slapping his forehead and exclaiming "There's cross terms! Stupid… ugh… That's why. Okay". We interpret this as indicative of a shift to the algorithmic math frame because the student is more carefully performing algebra to catch his prior mistake. In revealing the correct answer, the instructor prompts the student to switch frames to a more productive one. When the student was more focused on the justifications of why the exponential term is zero (using the *conceptual math* frame), he missed noticing the new factors arising from the cross terms in the wave function. Switching to the algorithmic math frame allowed him to notice those terms.

Table 1: Frames of interest and examples

Frames	Features	Example
Algorithmic Math	More Algebra Less discussion	Evaluating an Integral (e.g., "I think you are missing a minus sign")
Conceptual Math	More sense making discussion Less writing	Setting terms to zero due to orthogonality (e.g., "These terms are orthogonal so the integral is zero")
Physical Systems	Insight about the real system and physical world	Dimensional analysis (e.g., "What are the units of wavefunction?")

Conclusions and implications

In this study through observing students' epistemic activities we could identify the state of students thinking associated to three discrete frames including algorithmic math, conceptual math, and physical systems. We presented one brief example of a student switching frames to productively and correctly solve a problem. While he switched from *conceptual math* to *algorithmic math*, we do not mean to imply that *algorithmic math* is universally more productive than *conceptual math*. Rather, what counts as productive framing depends strongly on the problem context, and different frames may be productive at different times within a problem. Students' difficulties in quantum mechanics -- such as thinking that the probability density is time independent for a superposition of two stationary states, as this student does -- may simply be the result of unproductive framing and not fundamental inability to solve these problems or to do the math associated with them.

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Acknowledgments

Team Awareness Support for Collaborative Argumentation in Higher Education: A Qualitative Multiple-Case Study

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Abstract: This paper explores the role of team awareness for enhancing the quality of collaborative argumentation. Ten groups of Computer Science students (N = 28) participated in a longitudinal study for arguing on ill-structured problems where they received two types of team awareness prompts embedded in collaboration scripts. The analysis of argument maps indicates that the social awareness script has a moderately higher positive impact on the quality of argumentation compared to the behavioral awareness script.

Introduction

Collaborative argumentation is regarded as a highly effective instructional strategy for higher education but it is also linked to big challenges for students who need to take care of the group dynamics while learning how to argue and arguing for learning the context (von Aufschnaiter, Erduran, Osborne, & Simon, 2008). Collaboration scripts can facilitate these argumentation processes (Stegmann, Weinberger, & Fischer, 2007), and when combined with task awareness support (i.e. information on group members' knowledge), scripts can help students acquire deeper understanding of domain concepts (Gijlers, Weinberger, van Dijk, Bollen, & van Joolingen, 2013). Nevertheless, for completing a collaborative task successfully students need to know more about their own work status and their collaborators' activities (Belkadi, Bonjour, Camargo, Troussier, & Eynard, 2013). Two types of team awareness are concerned with information on group dynamics. While behavioral awareness is regarded as students' knowledge about their activities in the group (Janssen, Erkens, & Kirschner, 201), social awareness is regarded as students' knowledge about the functioning of the group as perceived by their collaborators (Phielix, Prins, Kirschner, Erkens, and Jaspers, 2011). However, little is known as to how support of team awareness can be combined with scripts for supporting collocated collaborative argumentation and to what extent different team awareness types (behavioral and social) influence the quality of collaborative argumentation when embedded in a script.

The study at hand aims to shed light on the effects of different team awareness prompts for enhancing (a) *team awareness processes* and (b) *the quality of collaborative argumentation*. Moreover, this study investigates (c) *the relation between different team awareness processes and the quality of collaborative argumentation.*

Methods

This study employs a longitudinal multiple case study design (Yin, 2009), in which each of the ten groups of Computer Science students (n = 28, in groups of three or two) is conceptualized as a 'case'. Half of the groups were supported by a behavioural awareness script (behavioural awareness script condition). This script included behavioral awareness prompts, i.e. reminders for performing participation check, performance comparisons and coordination checks. The other half of groups was supported by a social awareness script (social awareness script condition). This script included social awareness prompts, i.e. reminders for assigning roles, keeping an open mind and being friendly in the group, openly evaluating their performance.

The learning task for all groups was to argue over four sessions of 75 minutes each on ill-structured problems. Firstly, they were provided with the problem case on a learning related problem, the task description and the theory at hand in paper form. Their main task was to argue for and agree on the best solution to the problem and then transfer their arguments into a joint argument map using the online argumentation mapping tool *Rationale* (www.rationaleonline.com) while collaborating. At regular intervals during the collaboration students were given either social or behavioural awareness prompts depending on their condition and had to discuss and apply them in the group. The video recordings from the collaborative argumentation sessions as well as the argument maps produced throughout each session are being analysed using qualitative methods.

To measure the *quality of collaborative argumentation*, we first defined the levels of collaborative argumentation as low, medium or high based on criteria of formal completeness and evidence sufficiency of the arguments in the maps. Half of the argument maps were coded by two coders until a Cohen's *Kappa* value of .70 was reached. Subsequently, all argument maps from all four sessions across the ten groups (40 maps in total) were coded for each group for each of the four 75 minutes session individually to assess the change in quality of collaborative argumentation over time.

The *quality of team awareness processes* was examined using content analysis (Krippendorff, 1989). We coded for students' references to the prompts and their application (e.g. engagement in mutual performance monitoring) based on video segments from the five minutes before and after introducing each team awareness prompts to the groups in both conditions.

Results

The analysis for the *quality of collaborative argumentation* as derived from the comparison of all argument maps between conditions shows that groups in the *social awareness script* condition did better in raising their level of argumentation from low or medium to high than the groups in the *behavioural awareness script condition*. More specifically, the comparison of the quality of argumentation between the first and the fourth session for collaboration revealed that the groups in the *social awareness script* condition increased the level of formal completeness of their arguments by 29.4 % as opposed to 6.11 % in the BAS condition. However, the evidence sufficiency level of arguments in the *behavioural awareness script condition* condition increased by 3 % as opposed to 2.21 % in the SAS condition. In future work, the results of the content analysis for the *quality of team awareness processes* from the videos will be examined for mediation effects of team awareness (behavioral and social) on the quality of argumentation.

Conclusions and implications

The moderate improvement in the quality of collaborative argumentation in the *social awareness script* condition indicates that information about the functioning of the group as perceived by their collaborators could be more helpful for enhancing collocated collaborative argumentation in higher education than information about activities in the group. In this respect the ongoing content analysis of the group discussions on the different team awareness prompts might shed light on *the relation between different team awareness processes and the quality of collaborative argumentation.*

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Gender Differences in STEM Career and Educational Choices of Alumni of an Urban, Museum-Based After School Program

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Abstract: We report findings from a retrospective, longitudinal study of the STEM career and educational choices of alumni of an urban, museum-based OST program. Surveys were sent to 170 alumni and 28 were interviewed. Results were analyzed through a hybridity framework around how they remembered the program compared to experiences at home, in formal school and with their social circles. Findings include a major increase in female STEM career interest while in the program, compared to their male peers. This increase was related to how they perceived staff and the formality of the program. There was no relationship with race or SES.

Introduction and framework

Retrospective studies looking at the long-term impacts of OST STEM experiences have suggested that they can provide opportunities to engage in STEM-related activities and practices, ways of thinking, and communities. They act as an "…anchoring force in the learning ecologies of many individuals and communities..." (p. 195) (Brevan, 2013). McCreedy and Dierking's (2013) investigation of the long-term impact of six OST programs for girls found they helped to shape women's personal identities and life trajectories related to science. Learning happens across the physical spaces of home, school, informal institutions and communities and across diverse social material and other contexts (Bell, Bricker, Reeve, Zimmerman & Tzou, 2013). A key framework for our analysis is hybridity - a phenomenon where educators and learners form a new environmental place by combining elements of home, society and the classroom to generate knowledge, identity and discourse (Calabrese Barton, Tan & Rivet, 2008). It is as an effective way to look at how girls in particular view the scientific learning community since it addresses issues of identity, knowledge, skills and goals from a broad sociocultural perspective.

Located in a diverse area of a major city, the Museum of Science and Industry, Chicago has run the Science Minors and Achievers program (hereafter: SMA) program for over 10 years. SMA is a youth development program focused on scientific inquiry, public speaking/self-efficacy and college readiness. We designed a retrospective, mixed methods study of program alumni to answer the research questions: "What impact did participating in SMA have on STEM educational and career interests of alumni? And how do those impacts differ among genders?"

Methodological approach

We reached out to 573 past participants (alumni). The survey instrument included measures for science attitudes, program memories, educational/career paths and demographics. The poster will report on all measures, but this proposal focuses on educational/career path. The research team developed a new Hybridity Scale, which asked respondents to rate, on a scale of 1-10, whether the program's physical space, staff members, and social environment each felt less or more like 1) home 2) school and 3) being with friends. To measure their educational and career interests, we asked participants to tell us what college majors/careers they were interested in before high school, after high school, before college, after college and what career they were currently in. We received responses from 170 alumni (mean age = 21 [SD=2]). They self-identified as 67% female and 33% male. Racial and ethnic makeup was 43% African American, 24% Latino/Hispanic, 15% White (non-Hispanic), and the remaining categories were less than 6% each. 28 respondents were interviewed.

Analysis

Responses to the educational and career interest questions were dichotomously coded as either "STEM" or "Non-STEM", using a listing of STEM fields defined by the National Science Foundation (NSF, 2014). STEM career interest increased while participants were in the program, from 51% when they started the program to 71% when they graduated, followed by a sharp decline in college (Figure 1). A repeated measures ANOVA across all six time levels finds this gender difference as statistically significant, $F(5, 62) = 3.97$, $p < .01$, $\eta^2 = .06$. Neither race nor SES was statistically significant as a covariate at the $p = .05$ level. We found no relationship between final STEM career destination for females and their attitude scores, age, SES, or race. However, we did find a

relationship between final STEM career destination for females and the mean of their scores on the Hybridity Scale questions about schooling, $F(1, 49)=5.10$, $p < .05$, $\eta^2=.09$. Females who chose a STEM career were more likely to report that their experience in the program was *less* like their school experiences. Also, changes in STEM educational/career interest over time was related to how all respondents perceived staff in the program (Staff Formality), $F(5,63) = 1.476$, p=.01, $\eta^2 = .437$. Women's Staff Formality scores were higher (5.7) than men (5.1), a significant difference, $F(1, 168) = 5.91$, $p <.05$, $\eta^2 = .03$.
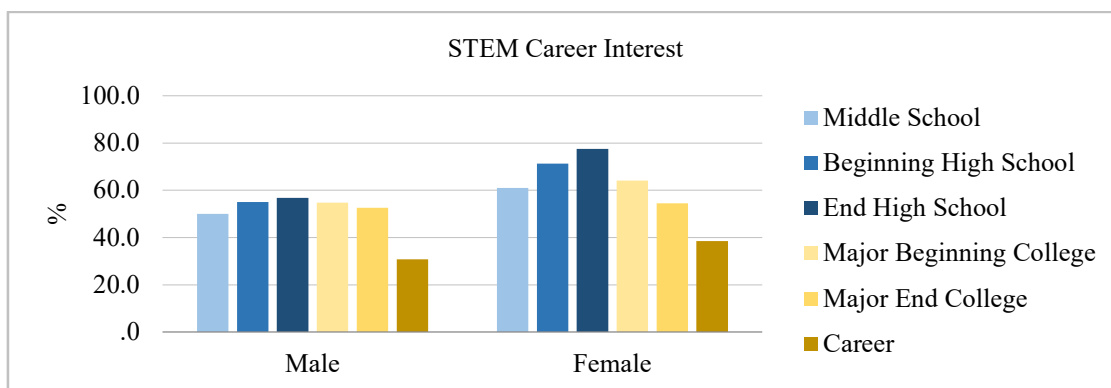
Figure 1. STEM educational/career interest. Blue represents when respondents were in the program.

In the interviews, we noticed differences between how males and females describe the staff in the program. Males referred to staff mostly as mentors (75%), then friends (50%) and teachers (25%) while females referred to staff mostly as teachers (75%), then friends (20%) and parents (20%). Only 10% of females referred to staff as mentors. Female comments about staff as teachers often focused on their scientific knowledge: "…personality wise less like school teachers but they taught us everything, like the school teachers".

Findings

The sharp increase in female STEM career interest while in the SMA program is striking. This increase may be due to females' relationships with and perceptions of the program staff. Other researchers have reported that a closer relationship between females and program staff is more conducive to development of STEM interest (Campbell, et al., 1995). Interviews suggest that while some females viewed staff as teachers, they viewed them as "the best type of teachers". Rather than being a simple commentary on teaching style or personalities, the term reflects their regard to the staff's scientific content knowledge. In interviews, females were also more likely than males to refer to teachers as family (i.e.: fictive kinship), reflecting a complex relationship not easily pigeonholed.

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Acknowledgments

Utilizing Eye Tracking Technology to Promote Students' Meta-Cognitive Awareness of Visual STEM Literacy

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Abstract: During a two-week summer camp designed to promote student visual, scientific, and data literacy through infographics, our team developed a curricular component involving viewing infographics while being recorded by an eye-tracking machine. Students viewed data collected by the eye-tracker and reflected on their own process of visual engagement. This activity enabled students to gain metacognitive awareness of their own perceptual and interpretive processes, supporting their performance during the rest of the summer camp.

Keywords: metacognition, STEM literacy, visualization, learning environment design

Introduction

We articulate our aims for, and preliminary findings from, a digital eye-tracking exercise developed as a curricular component of a ten-day science summer camp, Infographic Expression, (InfoX). The objectives of InfoX were to engage high school students in a meaningful process of analyzing visual representations of quantitative and scientific data and to support student understanding of how they process mixed media information by having them identify a topic of personal or scientific relevance and author a science news infographic. The eye-tracking exercise provided students with an experience in a cognitive development laboratory to nalyze their own embodied engagement with diverse visual representations, and produced a large data set for later manipulation, bolstering students' understanding of their visual perception and interpretation.

Theoretical framework and related literature

We utilize a socio-cognitive framework, seeing learning as social or interpersonal activity being appropriated to the intrapersonal or intramental plane (e.g., Wertsch, 1991). Inspired in part by instructional models such as Palincsar & Brown's (1984) reciprocal teaching, we seek to design a learning environment with cognitive tools for metacognitive awareness of visual perception and interpretation. In this effort, we aim to adapt research on metacognition (e.g., Schoenfeld, 1987), and meta-representational competence (e.g., diSessa & Sherin, 2000).

Research context, data sources, and methods

One objective of InfoX was to expose students to scientific processes and university laboratory experiences. Accordingly, our team developed a curricular component in collaboration with staff trained in eye-tracking from our institution's Cognitive Development Lab. The desired outcomes for this experience were for students to gain deeper insight into how they process visual representations. We developed a series of infographic visualization trials aimed at providing an educative experience for learners (given our relatively small dataset, we did not aim to make generalizable theoretical claims regarding basic perception and cognition). We selected a series of six student-generated infographics, and coded each into four areas of interests (AOI). We developed a set of open ended and closed questions for each. Seven InfoX students participated in two tasks utilizing these prompts.

The first task was for students to answer a series of four pre-assigned questions using an infographic presented to them on a computer screen equipped with an eye-tracker. These questions concerned quantitative and qualitative information, the credibility of the infographic, and data that could only be found in specific data visualization components. There was no time limit. The second task allowed students thirty seconds to study a novel infographic and try to remember what they deemed most important. Students were situated in front of a computer in the Cognitive Development Laboratory and a technician explained the equipment and process to each student individually. The eye tracker would trace a student's gaze in real time, record changes in the dilation of the pupil, and quantify the amount of time spent in each AOI. Afterwards, the quantitative data was stored in a large spreadsheet, and students could watch as a red line overlaying the original image re-created where their gaze went. Students were then escorted to a second room to complete a questionnaire regarding their answers to specific questions, what they recalled, where they believed their attention was focused, and so on.

We, as instructors of InfoX, transformed the raw output data into a series of visualizations to share back with students. Prior to seeing these results, the students presented the infographics they had seen the day earlier to the rest of the class and explained how they believed they had processed the information. Then, through a series of graphs and charts representing data collected from the eye-tracker, the instructors demonstrated where students'

gaze actually went, how they responded to questions, and for how long participants focused on each AOI. Students were surprised by some of these results and spent time reflecting on trends in the data. Students then had a second opportunity to explain where they looked and how they engaged the visual information. Collectively, the class offered feedback for each of the experimental infographics and reflected on how they each processed visual representations differently.

Data sources for this analysis include records of the above interactions from field notes and video recordings of class sessions, informal interviews of participants, artifacts created during the eye-tracking sessions, and students' final infographic products. Our research method involves coding and quantifying instances of student metacognitive reflection regarding their visual processing after the eye tracking activity.

Figure 1. Student viewing an infographic in front of the eye tracking machine. Figure 2. Students debriefing the results of the eye tracking exercise as they observe the AOI's (in red, on left) and gaze tracker (in blue on right).

Analysis and future directions

The eye-tracking experiment and analysis took place in the first three days of the ten-day InfoX program. As such, the experience and analysis of the eye tracking exercise illustrated and drew on student intuitions and prior knowledge of visual perception. This provided a springboard for discussion regarding effective presentation of data, visual appeal, and the students' own scientific and visual literacies. Later in the program students participated in activities concerning graphic design, and "good" visual representation practices. The eye tracking activities appeared to provide a useful foundation for students, as they frequently referred back to it while they spent the next seven days of the program developing and designing their own science news infographics. Students remarked about creating visually appealing and diverse AOI's, parsimony through bulleted texts, redundancy in qualitative and quantitative data, and overall 'flow' of their infographic based on the gaze analysis of their own viewing. In several cycles of peer feedback, students referenced their own tendencies as well as trends that they eye tracker captured. Students also recognized variation in these patterns that correlated with gender and age of participants, leading to further discussion about intended audiences and background knowledge of the viewer. It appeared that students' increased understanding of selective and sequenced attention bolstered their metacognitive perceptual abilities and informed the design of their final infographic products.

The InfoX summer camp was part of a larger project exploring how infographics support STEM literacy. In this first iteration of InfoX we found that the eye-tracking activity engaged our students, grounded their understanding of visual literacy in an embodied experience, and offered opportunities to bolster their intuitions of how they typically engage visual data. We see promise in further developing activities capitalizing on the affordances of these technologies to support metacognition regarding visual perception and interpretation, and, ultimately, contributing to scholarship on perception, visual literacy, and data visualization (Lai et al, 2012). Accordingly, we will run a second iteration of InfoX in 2016 to follow up on preliminary findings of this study.

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Embodied Actions to Support Spatial Thinking in STEM: Structural Diagrams in Organic Chemistry

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Abstract: This paper reports on an analysis of a learning environment designed to promote embodiment around spatial concepts in organic chemistry. The analysis indicates that instruction via embodied actions does not produce detectable difference on an outcome measure, but follow up analyses indicate that the proportion of spatial language used during learning may provide insight into students' developing spatial thinking.

Introduction

Students must reason about complex spatio-temporal dynamics across the science, technology, education, and mathematics (STEM) curriculum. Some have claimed that individual and group differences in spatial ability (e.g., spatial visualization, mental rotation) can explain who persists in STEM and what career prospects an individual might expect (Uttal et al. 2013). This line of research argues that improving spatial ability should positively impact student achievement and retention and has given rise to training regimes that target domain-general spatial ability (e.g., Sorby, 2009). However, despite a principled rationale behind such efforts, there is little convincing evidence to date that such training is durable, applies unilaterally across STEM fields (Miller & Halpern, 2013), or that measured improvements in spatial ability are causally responsible for improved course-based achievement (Stieff & Uttal, 2015).

Addressing the reform goals of the STEM curriculum may require a reconceptualization of spatial literacy. Rather than targeting domain-general, abstract spatial competencies, promoting *spatial thinking* may be more generative to meeting the goals of broader reform (National Research Council, 2006). Spatial thinking is defined as a "constructive amalgam of three elements: concepts of space, tools of representation, and processes of reasoning" (p. 3). A student is considered spatially literate when they are able to invoke domain-relevant spatial concepts (e.g., symmetry, geometry) to structure problems and reasoning, while also mastering the tools of representation of that domain (e.g., diagrams, computer visualizations). Spatial thinking is thus broader in scope than spatial ability and provides a different lens to motivate learning environment design. Spatial thinking is also more general and "multifaceted in its operation: just as there is no single recipe for how to think verbally or mathematically, there is no single way to think spatially" (p. 26).

One approach to support spatial thinking in STEM may be to foster *embodiment* around spatial concepts, tools of representation, and processes of reasoning. In the learning sciences, embodiment is a broad construct that represents a collection of theoretical and analytic approaches. For preciseness, embodiment here is consistent with the *grounding* metaphor (Barsalou, 2008). The grounding metaphor proposes that semantic knowledge relies, at least in part, on the activation of prior perceptuomotor states. Learning environments that aim to promote embodiment should thus be engineered to ground disciplinary concepts in bodily states (collectively, *embodied actions*) that can be accessed offline by the learner. Indeed, there is evidence in extant research that embodied actions directly influence and benefit the cognizer on spatially demanding tasks. Gesture serves as one well-studied case: individuals who spontaneously gesture while solving traditional mental rotation problems perform better than their non-gesturing counterparts and this benefit can be achieved through instruction (Chu & Kita, 2011). Moreover, spontaneous gestures affect solution strategy on spatial tasks: on a gear direction task, individuals were more likely to uses a perceptuomotor strategy over an abstract algorithm when they had free movement of their hands (Alibali, Spencer, Knox, & Kita, 2012).

Here, I report on a study of naïve students as they learn how superficially disparate structural diagrams in organic chemistry can represent the same spatial relationships in a molecule. This study uses a responsive computer interface (reported in DeSutter & Stieff, 2014) that employs face-tracking technology. As the learner shifts their vantage point to a vantage encoded in a disciplinary diagram, the 3D structure is swapped with an equivalent 2D representation. This learning environment is designed to ground the learner's perception of disciplinary diagrams with congruent bodily states. It this physical alignment better grounds the learner's understanding of spatial transformations between disciplinary diagrams, I predict that the treatment condition should produce more accurate diagrams than a control group using only a mouse.

Present study

This investigation focuses on one facet of the NRC framework: whether embodied actions support *understanding concepts of space* in the domain of organic chemistry. Participants were asked to use the software interface to generate a Newman and Dash-Wedge diagrams of multiple molecular structures. An example of what a student would see in the computer visualization as well as the correct diagrams is presented in Figure 1.
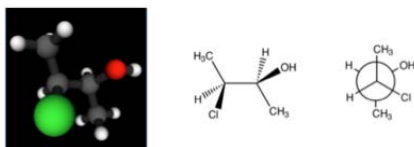
Figure 1. Equivalent representations of (*2S,3S*)-3-chloro-2-butanol.

Participants (*n* = 10) were recruited from a population of students enrolled in an undergraduate general chemistry course. Participants were randomly assigned to either the embodiment (*n* = 6) or the mouse (*n* = 4) condition. Participants read a text on carbon geometry and another detailing the spatial relationships in both diagrams. An atomic color guide and sketching worksheets were provided. Participants completed assessment items outside the software interface that ask them to draw diagrams for three molecular structures. Participants then completed the Guay's visualization of viewpoints perspective taking test.

Method

Participants were videotaped. Verbal utterances were transcribed verbatim. Diagrams on the assessment items were scored for binary accuracy. Participant's speech was analyzed for spatial utterances. Spatial utterances were identified as segments of speech that contained a subject, verb, and spatial qualifier. The total count of spatial words was then computed as a proportion of total speech, yielding a proportion of spatial utterances metric controlled for participant verbosity.

Results and discussion

I hypothesized that participants in the embodiment condition should outperform the mouse group (control) on measures of diagram accuracy. A between-subjects ANOVA revealed that there were no detectable differences in average achievement between the mouse ($M = 0.81$, $SD = 0.24$) and embodiment ($M = 0.59$, $SD = 0.31$) condition, $F(1,8) = 1.60$, *ns*. Thus there is no evidence that the treatment group performed better than control, although this may also be the result of a Type II error.

Despite this limitation, language is intimately related to human concepts and serves as another proxy for underlying spatial conceptual knowledge. The analysis revealed that the proportion of spatial utterances was not correlated with participant spatial ability ($r = 0.26$, *ns*), but that it was negatively associated with the accuracy of participant drawings ($r = -0.65$, $p < 0.05$). These findings indicate that participants who use more spatial language when learning may be demonstrating a less stable understanding of spatial concepts than those who do not. This finding motivates a more careful consideration of the role of language in spatial thinking and suggests that spatial language may be a more sensitive observable outcome of developing spatial thought.

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How Teachers Seek and Learn From Negative Feedback

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Abstract: The proposed study seeks to explore teachers' responses to negative feedback in a professional development workshop. 36 STEM teachers from a secondary school in Shanghai, China will learn about concept mapping over three sessions and they will be asked to choose either a positive or a negative feedback at the end of each lesson. The data will be used to examine whether teachers' choices of negative feedback correlate to their beliefs about intelligence, learning process, and performance.

Keywords: negative feedback, theory of intelligence (TOI), performance, teacher professional development

Introduction

Feedback has powerful impact on learning and performance. However, past studies on feedback mainly focused on students' responses and there has been scant literature on how teachers seek and learn from feedback. Given the pervasiveness of feedback in learning and teaching, understanding teachers' responses to feedback is equally important. Moreover, several studies about feedback on teachers' learning and performance have demonstrated that teachers could also benefit from feedback (Auld et al., 2010; Scheeler, 2008).

Among the studies demonstrating the correlation between feedback and learning, few studies have examined how learners seek, perceive, and process feedback. However, untangling effects of feedback "depends more on the level at which the feedback is aimed and processed than on whether it is positive or negative" (Hattie & Timperley, 2007, p.98). Thus, it is essential to examine feedback effects from the receiving end, by understanding the learner's feedback-seeking behavior.

Both positive and negative feedback can have beneficial impact on learning. However, negative feedback is often perceived as a threat or a hurt, even when it is constructive. Nonetheless, negative feedback is an inevitable part of learning. Thus, it is critical to understand how learners respond to feedback so we could help them learn from it.

Prior research exploring learner's negative feedback-seeking behavior has revealed that the frequency of choosing negative feedback is positively correlated with learning performance and standardized achievement tests (Cutumisu et al., 2015). Finkelstein & Fishbach (2012) also noted that experts have tendency to seek and respond to negative feedback while novices seek and respond to positive feedback. On the basis of existing literature, our research will explore whether teachers' choices of negative feedback (1) Correlate to their beliefs about intelligence, (2) Change along the learning process, (3) Correlate to their final performance.

In this study, we hypothesize that: (1) The more growth-minded participants will show higher acceptance of negative feedback when compared to more fixed-minded participants; (2) Participants' choices of negative feedback will increase as they progress on the learning task, thus demonstrating higher acceptance of negative feedback at higher levels of involvement in learning; (3) The more negative feedback participants choose, the better they will perform in final assignment when controlling their prior knowledge.

Methods

Participants

36 STEM teachers in a school-based professional development workshop from a public secondary school in Shanghai, China will participate in the "Teaching with Technology" workshop. The teachers will learn technology tools that have potential to enhance their teaching and learning. A subtopic of this workshop will be about concept mapping. The study will focus on participants' learning in 3 consecutive sessions.

Procedures

The study will take place in the spring semester of 2016. Figure 1 outlines 5 main components of the study. (1) Participants will begin with a survey of demographic information and the Theory of Intelligence (TOI) scale (Hong et al., 1999). They will then be asked to draw an initial concept map on a passage they have never read,

which will be selected from the latest issue of a popular science magazine. (2) Participants will then engage in Lesson 1, learning principles about concept map and the ways to create one by drawing and by using specific software (**Instruction & Practice #1**). Following the lesson, they will complete and submit their first concept map (**Assignment #1**) on a new passage, and will be informed that their assignment will be evaluated by 3 content experts and 3 concept mapping technology experts. They will also be asked to preselect either a positive feedback or a negative feedback from each evaluator (**Preselect Feedback: 1st Round**). Evaluators will then provide feedback based on the participant's preselected type (**Provide Feedback: 1st Round**). Afterwards, participants will read the feedback they chose (**Read Feedback**). (3) & (4) Participants will subsequently take Lessons 2 & 3, completing the "Instruction & Practice --> Assignment --> Preselect Feedback --> Provide Feedback --> Read Feedback" cycle as described in Figure 1. (5) Participants will take final surveys about their learning experience from the negative feedbacks and their understanding of concept mapping.
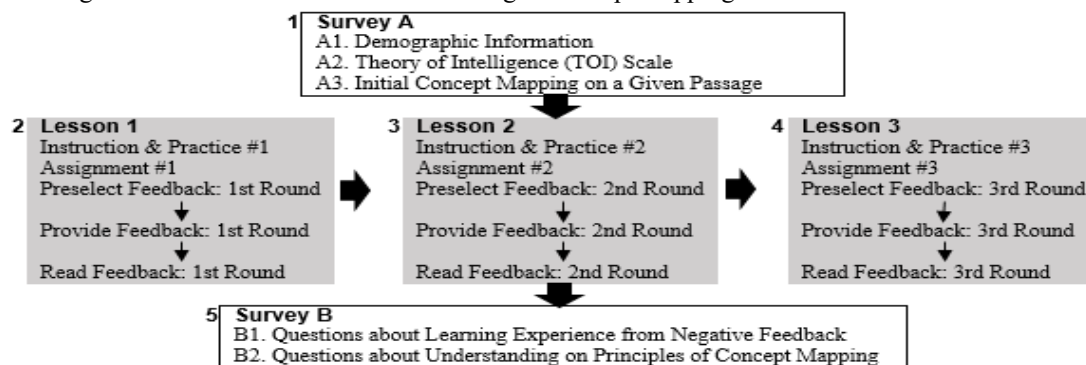
Figure 1. Five main components of the study.

Measures

The study will include 4 main sources of data. (1) Negative Feedback (NF). We will measure the number of times a participant choose negative feedback each time and in total. (2) Theory of Intelligence (TOI). TOI scale items will be reverse-scored so that higher scores will indicate endorsement of a growth mind-set while lower scores will indicate a fixed mind-set (Moser, et al., 2011). (3) Participant's Performance on Concept Mapping (PP). Each participant's final assignment will be scored by 6 evaluators, then the mean value of 6 scores will be used as the final performance score. (4) Prior Knowledge on Concept Mapping (PK). PK will also be scored by the mean value of 6 evaluators using the initial concept map participants' created prior to Lesson 1.

Expected results and discussion

Correlation analysis will be conducted to test and analyze for hypothesis (1) and (2). Hypothesis (3) will be demonstrated through partial correlation. This study will add to our existing knowledge of the role that negative feedback has on teacher learning as well as provide insights about the ways teachers perceive, engage and integrate negative feedback during their learning process. Consequently, we hope the findings will shed light on the incorporation of negative feedback in teacher professional development programs.

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Collaborative Knowledge Networks to Facilitate Knowledge Building in Robotics: A Longitudinal Study

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Abstract: The purpose of this longitudinal study is to establish an innovation network to explore science topics using robotics as the focal innovative activity, through Knowledge Building pedagogy and technology. This study aims to develop a mutually supportive interaction among more and less sophisticated student groups and show how a community with extended knowledge building experience (the innovative core) can create ripple effects, with consequent dynamic interaction throughout the network, to the benefit of all.

Introduction

The growing importance of innovation in modern societies has resulted in pressure on schools to develop innovative capacity in their students. Although the most common response of education systems has been to focus on the testing and teaching of skills believed essential for innovation (Griffin, McGaw, & Care, 2011), another line of development has sought to engage students directly in idea-driven knowledge creation (Scardamalia & Bereiter, 2014; Tan, So, & Yeo, 2014). Contributing to this more direct approach has been technology enabling relative novices to do authentic invention and engineering design (Bauerle & Gallagher, 2003) and the development of ways to support creative work with ideas in educational contexts (Scardamalia & Bereiter, 2014). This research will build on both these developments and bring in a third element: what Gloor (2006) calls "innovation networks." These are networks of people who not only share ideas, but generate and refine new ideas through the dynamics of networked social interaction. This research will integrate these three elements experimentally, using robotics as the focal innovative activity, supporting knowledge creation through Knowledge Building pedagogy and technology (Scardamalia & Bereiter, 2006), and establishing an innovation network. We have chosen to build on Gloor's work (2006) on innovation networks because, although it has focused on adults working in innovation-intensive organizations, it offers an analytic framework that addresses concerns important in education at all levels. Gloor identifies three forms of network engagement: (1) Collaborative Innovation Network- at the core is a team of self-organized and intrinsically self-motivated people who have a collective vision; (2) Collaborative Learning Network- people with shared interests join the core community to discuss new ideas, learn, and apply innovations; (3) Collaborative Interest Network- people at the periphery, often lurkers, seemingly share interests but do not contribute content. We may think of these different networks as concentric circles, with a ripple effect from innovative core to periphery. The innovative potential is not unidirectional, however. Innovative ideas may occur throughout the extended virtual network, with lurkers at one point becoming key innovators at another (Gloor, 2006). The flow of ideas inward and outward in the network structure and the movement of individuals between circles will be an important focus of the proposed research.
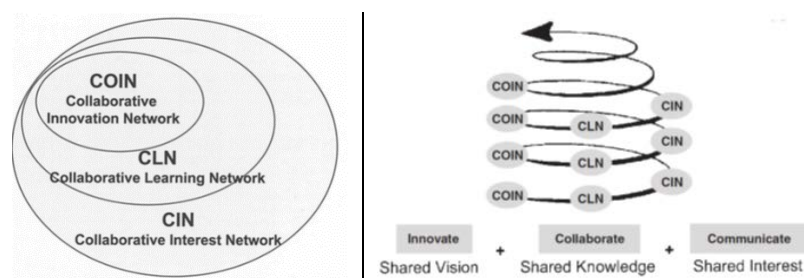
Figure 1. Collaborative Knowledge Network structure and innovation ripple effects (Gloor, 2006).

The reason that robotics is chosen as the focal activity is that while robotics is shown to have positive effects on developing 21st century skills as well as STEM education (Attard, 2012; Bers & Portsmore, 2005; Gura, 2012), educational robotics often goes on in a competitive way, resulting a dichotomy in the class with some well-developed projects, and some projects in their early stages of development. However, it is important to have a knowledge community in which there are not insiders and outsiders but one where everyone can move between

roles of doer, explainer, and critic. In this study, we will employ Knowledge Building as the educational framework because it is an extensively researched approach that directly pursues knowledge creation as a goal (Bereiter & Scardamalia, 2014) and because it incorporates technology specifically developed to support collaborative knowledge building and create collaborative knowledge networks (Scardamalia & Bereiter, 2006, 2014).

Method

This research would be the first longitudinal analysis of network theory in educational contexts. This study will explore forms of engagement and knowledge work within and between mature and novice knowledge building classes in two different schools as students move from Grade 3 to 5. Science topics (e.g., pulleys and gears, forces and movement) will be explored using robotics: one school with mature Knowledge Building teacher and class, the other with both teacher and students new to knowledge building. The online environment will be Knowledge Forum® (KF) - a web based discourse medium specifically designed to support production and refinement of community knowledge to advance understanding of the world and effective action through social interaction.

Plan of analyses and research questions

Social network analysis, discourse analysis, and qualitative analysis will be employed to examine collaborative knowledge advances, including changes in network configuration over time and advances in science and robotics knowledge. The data required for this study will be collected from students' discourse in KF, as well as their in-class activities. Each week, social network analysis will be employed to analyze these data to identify types of collaborative knowledge networks based on connectivity (betweenness centrality in social network analysis terms) and density of the networks. Also, discourse analysis will be employed to assess the quality of student discourse. In this part, the research aims to address the following questions: How do students form a collaborative knowledge network? How do innovative ideas ripple through collaborative networks? How does the core innovative network (i.e. the mature knowledge building class) expand to include students in the periphery (i.e. the novice knowledge building class), with those students then advancing their collective work? Can this process be facilitated through more effective knowledge practices? Which students form different networks? How does their collaboration change over time? When and how each student migrates from one network to another? We will also conduct qualitative analyses, attending classes to carefully observe students discussions and record changes in interest, knowledge, or vision. Also, if the results of social network analysis show transition from the periphery to the core innovative network, we will conduct interviews with students and teachers. In this part, the research aims to examine how interest, knowledge, and vision change as a result of immersion in a collaborative knowledge network. These results will then be used to facilitate the formation of more dynamic interactions.

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Design Experiments Towards Practice-Based Learning Analytics: A Student Perspective

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Abstract: Practice-based learning activities are an important aspect of education, particularly for science, technology, engineering and mathematics (STEM) subjects. However, their hands-on and open-ended nature makes them very challenging for students to control their own learning and reflect on it. In this poster presentation, we present our method of generating visualizations that can effectively support students' learning process in such activities. In addition, we provide some feedback on two prototypes we generated.

Introduction

This poster presents work in progress aligned with the 2016 conference theme concerned with transforming learning and empowering learners in the context of practice-based or experiential learning and physical computing. We start from the premise that hands-on experiences are an essential part of teaching and learning of STEM subjects, but note that there is little agreement on how STEM practice-based activities should be applied and assessed (Abrahams & Millar, 2008). Guidance in such activities is essential (Clark, 2009), yet difficult to provide due to various reasons. Whilst the field of learning analytics has highlighted the potential of tools to support teachers and provided instances of tools that can increase learner awareness and enable self-reflection in various learning contexts, practice-based learning has largely been out of the scope of current approaches. This is mostly due to the challenge of observing the diverse set of digital and non-digital activities that take place during hands-on learning (Worsley & Blikstein, 2014)

In the [blinded] project, we are exploring the teaching and learning of STEM subjects using physical computing kits during open-ended design tasks and aim to generate supportive learning analytics tools. In this poster, we focus on a series of design experiments and contextual inquiry approaches we undertook in order to get insights into classroom dynamics including students' interactions with learning materials, peers and teachers.

Contextual inquiry study

The project is following a mixed-methods design approach that consists of different design practices in several EU institutions. In brief, we have visited 10 educational institutions in four European countries, interviewed 25 STEM teachers and facilitators as well as 15 students and observed 9 hours of STEM classes, some of which we co-designed with the teachers. We present below a summarised set of opportunity areas for research and development, which informed the iterative design process of interactive tools and visualization prototypes paying a particular attention to the student perspective:

- Capture early programming and/or hands-on issues that students are encountering, and generate 'real time' visualizations of them;
- Leverage digital practices (e.g. use of digital tools like mobile phones or social media) within the learning environment, that combine context-aware, sensor and multimedia capabilities, to provide students with more accessible, context sensitive and media-rich opportunities to record their learning experiences;
- Provide a tracking system that captures and provides information of students' collaborative patterns within the learning environment to enable the measurement students' collaborative skills, and complement and enhance more qualitative observations made by the teacher throughout the course;
- Support replay and self-tracking by digital tools that can identify, record, and categorise steps or phases (hardware, software, face-to-face activities) within a given learning activity in order to empower students' self-tracking of errors, enhance self-reflection

Design experiments on practice-based STEM learning

We analysed two studies that focused on learners' and educators' experience with iterative version of a prototype of a visualization tool for practice-based learning activities. Our focus on this poster is to present preliminary findings regarding how students engage with learning visualizations of data originating from their practice-based work and how this has the potential to support students' reflections, discussions, and self-regulation.

Our initial prototype (shown on Fig 1) has the following key features:

1) The timeline contextualises all of the tracked aspects of a student's work over time and graphically depicts a given period of the work of a given student group.

2) It is interfaced with Instagram as means to integrate a simple photographic documentation stream into the visualization timeline.

3) It is accompanied with a simple set of buttons that would allow a student to input their current status: the Sentiment Feedback Box.

4) It explores students' movement throughout space over the course of a project with bluetooth transmitters.

Interviews with students revealed that our visualization interface could provide the basis for group reflection activities as well as self- assessment at the end of the project; having a visual timeline overlay that depicts different activities in the course of their work would help them obtain a better look at the process in "review" as well as help them communicate the full spectrum of their efforts; and the visualization interface could be useful for them in identifying and reflecting on possible shortcomings in their work process, or internal team communication.
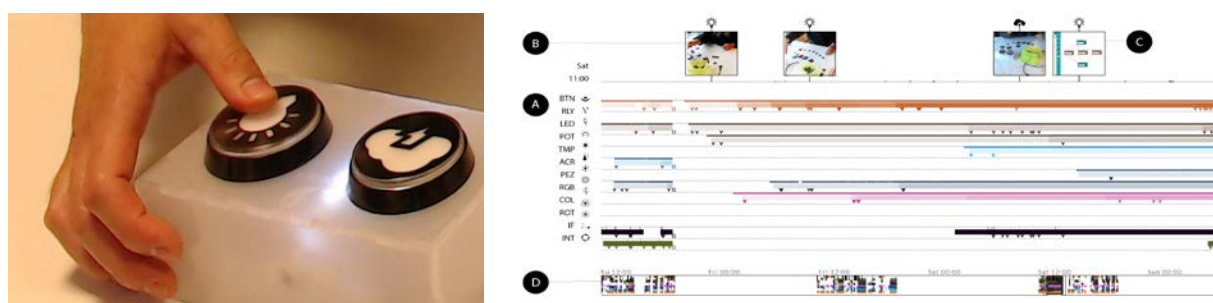
Figure 1. a. Sentiment buttons b. Learning process timeline

Taking the first study's results and the new technological developments on board we prototyped another visualisation prototype. Comparing to the first one, the second prototype had more focus on capturing the actual hands-on activities and their documentation in a more implicit, automated way. The main improvements of the second prototype were,

1) It integrated a novel physical computing learning kit, developed within the project, which allowed us, to register and display students' actions related to such hands-on activities,

2) We implemented a snapshot ability into each of the Sentiment Buttons such that when it is pressed, an overview camera placed on top of the workstation is triggered to take a picture of the working environment,

3) We continued to develop the time-based interface such that the student or teacher could interact with it, choosing a slice of time that is as small as one minute or expand the slice to the full length of the session (or session).

There were two main findings after the investigations of students' views on the improved visualisations: students appreciated the additional snapshot feature of the Feedback Button system as they felt that it was a fitting method for documenting "crucial" incidents during their work process; and students emphasised the value of timeline presentations as they allow teachers to see a summary of what we have done which is quite hard to be identified in such learning contexts.

Conclusions and implications

It is clear that technology can capture only certain aspects of student interactions during rich learning contexts such as practice-based learning. In this poster, we present our attempt to provide 'meaningful' visualizations that reflect important aspects of student experience, as well as provide feedback regarding their value for students.

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Provoking Mathematical Play Through Hidden Deep Structures

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Abstract: This paper examines a game, *Rolly's Adventure*, designed to support fractional reasoning. In particular, *Rolly's Adventure* used a quantity-based representation of fractions that players interacted with by choosing buttons that had an unspecified relationship to the fraction quantities. By developing, testing, and revising hypotheses as the game increased in mathematical complexity, the dyad uncovered the deep structure and secret operation (multiplication) underlying the game.

Keywords: mathematics, videogames, design

Rolly's Adventure is a game designed for and built on *LittleBigPlanet 2* (LBP), a game-cum-platform on the PlayStation 3. The game was designed around the deep structure of the behavior of fractions during multiplication, although the players were never told about this underlying pattern, following the design process for developing what I am terming *provocative objects*. Instead, the surface structure was designed to guide players towards discovering the deep structure through a series of thirteen game-based tasks that increase in mathematical complexity (see Chi, Feltovich, & Glaser, 1981). In particular, these tasks supported players in developing broad hypotheses, then revising and nuancing those hypotheses in response to the game's feedback.

Game and mathematics design

The Common Core State Standards for Mathematics (the CCSS-M; 2010) recognize fractions as a complex and important area of mathematical learning. "No area of elementary school mathematics is as mathematically rich, cognitively complicated, and difficult to teach as fractions, ratios, and proportionality" (Smith, 2002, p. 3). I defined fractions as "a *relationship* or multiplicative comparison between two quantities" (Lobato & Ellis, 2010, p. 58, italics original). Quantities are characteristics of objects that can be measured prior to any actual measuring, or even prior to a determination of *how* such a characteristic could be measured (Thompson, 1995).
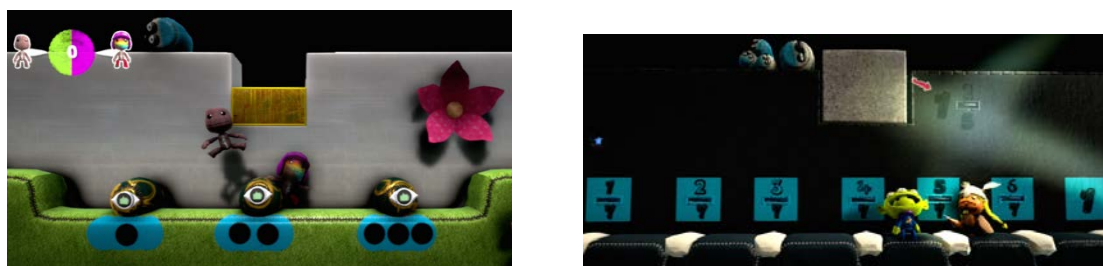
Figure 1. First game task (left) and last game task (right). The objects on the floor of the level are buttons, and the blue background identifies each button's label.

The game begins with a concrete (digital) representation of one half (see Figure 1, on the left), because although fractional notation is difficult for students (e.g., Mack, 1995), halving and doubling are understood even prior to formal schooling (e.g., Lobato & Ellis, 2010). Both of those concepts apply here, as the gold fraction block is one-half of the (w)hole, and it is through doubling that fraction block that the (w)hole is achieved. Players must use their perception to identify the relationship between the fraction block and the (w)hole, as no game structure guides players towards specific quantification. As the players progress, the fraction blocks become smaller and perception is no longer reliable, so notation is slowly introduced as it becomes both useful and necessary, as in Figure 1 (on the right), where accurately perceiving the fraction without notation would be difficult.

Participants and analysis

The data presented here is a small excerpt from a larger study, still under way. Two 7th grade boys (Nathan and Martin, both pseudonyms) from a midsize Midwestern city in the United States of America volunteered together for this project. Data analyzed for this paper included synced videotape and screencapture of their gameplay session with *Rolly's Adventure* (see Figure 2).
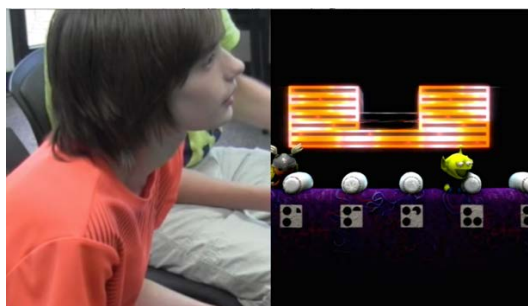
Figure 2. Martin leans forward to get a better look at the game task.

A coding scheme (Williams-Pierce, 2015) synthesized from Brousseau (1997), a mathematics educator, and Salen and Zimmerman (2003), both game designers, was revised in concert with the emergent patterns identified in the data. The analysis focused on the players' transition from attending to surface structures to deep structures within the game, through cycles of hypothesizing, testing, and revising. For example, during the first game task (Figure 1, on the left), Martin and Nathan determined the doubling relationship, and identified the number of dots on the button labels as corresponding directly to the number of gold fraction blocks produced when a button is activated. In other words, they had not yet identified the deep structure of multiplication. In later tasks they were forced to revise this hypothesis. For example, in Figure 2, the two fraction blocks represented two-fifths of the (w)hole, and they were no longer able to use this correspondence because each fraction block actually corresponded to one half of a circle on the button labels. By the end of the game (see Figure 1, on the right), both Martin and Nathan have revised their hypothesis to attend to the deep structure, and have discovered multiplication as the secret mathematical operation.

Conclusion

This poster will focus on sharing the path the players took to discover the deep structure embedded within the game, the mathematical language that they voluntarily produced during their play, and the game structures that supported the development of their final hypothesis. Additionally, I will highlight the potential of designing such provocative objects for developing understanding through mathematical play and discovery.

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Acceptance Model of Learning Technologies in Media Commons

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Abstract: In this poster, we present our preliminary work to build a theoretical model that could explain learners and instructors' technology acceptance behavior in digital media commons by exploring a new learning technology called *One Button Studio*. The poster shows the first stage of identifying constructs that affect perceived ease of use and perceived usefulness through semi-structured interview approach and suggests an extended version of the Technology Acceptance Model.

Background

When new learning technologies emerge, it is difficult to predict whether users will accept the technology. This is especially true in technologies installed in common learning spaces, such as media commons, where students and faculty members can freely use the facility for learning and instruction. With digital technology being increasingly common in our society, it is important to provide appropriate technology in a school setting (Teo, Lee, & Chai, 2007). With this in mind, we seek to extend the Technology Acceptance Model to explain which factors influence learners' intention to use a technology in such learning spaces.

Simplified recording studio facility

In order to achieve this, we chose *One Button Studio* due to its novelty and popularity among students and faculty members. The simplified recording studio facility that was built within the media commons of a U.S. land grant university, and it is in line with the university's maker commons initiative. The studio was designed to serve both students and faculty members to freely produce high-quality media, in a very simple and straightforward way. A user can record himself/herself in a studio environment with lighting and projectors by simply plugging in a USB drive and pressing a button. When a user is finished recording the video, another press of the button ends the recording session and downloads the media file to the USB drive.

(a)   (b)   (c)
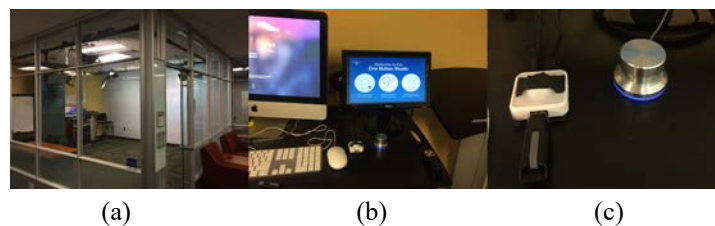
<u>Figure 1.</u> *One Button Studio*: the whole studio (a), the recording system (b), and the button (c).

Technology Acceptance Model (TAM)

The TAM is a theoretical model that has been widely used in the field of Information Systems to explain how users perceive and accept different information technologies. The TAM aims to understand how perceived ease of use and perceived usefulness and other external factors influence behavior and attitude toward technology (Davis, Bagozzi, & Warshaw, 1989). The TAM has been used in the education realm to identify user acceptance of learning technologies such as collaborative technologies (Cheung & Vogel, 2013), YouTube (D. Y. Lee & Lehto, 2013), and e-learning systems (Y.-H. Lee, Hsieh, & Hsu, 2011).

Methods

A semi-structured interview approach lets users talk about the technology and enables participants to discuss various factors that may play a role during the technology adoption process (Renaud & Van Biljon, 2008). A total of five participants were interviewed individually; participants were chosen based on their experience with the studio. The participants either personally used the studio or assigned studio-related work to students. The interview lasted about 40 minutes and questions related to technology, video production, and learning design were asked. Field notes were taken as we interviewed the participants, and audio recordings were captured for future analysis.

Preliminary findings

A list of constructs that may affect user acceptance were extracted from participant interviews. Many mentioned ease of use as the key feature of the studio and it was one of the appealing points for using the technology. One of the faculty members mentioned that some students chose to use their own personal device instead of the studio to produce video to complete assignments. Also, the majority of the faculty members mentioned that the studio produced good quality video without a user having to know a great deal about video production. In terms of perceived usefulness, participants indicated that the assignments to be completed in the studio were not always focused on the video artifact itself. Rather, the video was the culmination of a process in which the faculty member wanted the students to master. For example, some students worked in teams to complete a video project, where the focus of the assignment was around planning and storyboarding. Other instructors used the video artifact for self-reflection purposes, such as reviewing public speeches. Based on these responses, it can be inferred that usefulness can be influenced by two factors: artifacts and processes. Based on these preliminary findings we propose the following model to expand the pre-existing TAM to fit the learner acceptance of a new learning technology in the media commons.
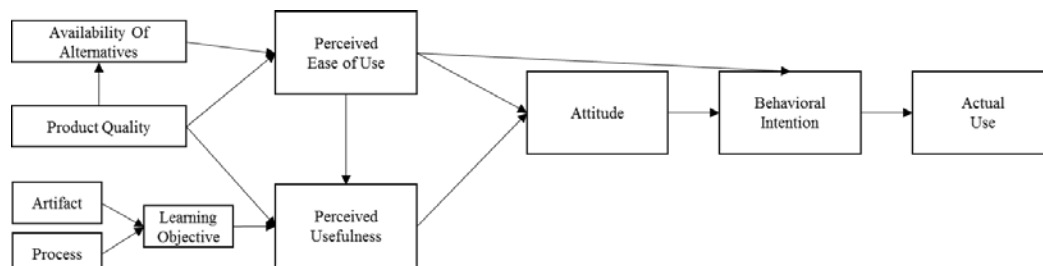
Figure 2. Extended TAM Model for media commons learning technologies.

Future directions

Based on the model derived from this study, we hope to further extend and verify the model through an extensive literature review and survey. Through the literature review, we hope to make modifications to the proposed model and enhance it to fit the theory, then develop survey materials. Moreover, we hope to conduct surveys with students as participants to statistically verify the model. This can contribute to how a user acceptance model for the media commons learning technologies can be theorized to explain learner behavior.

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Acknowledgments

Obtaining Rich Data in Augmented Reality Settings: A Comparison of Three Data Collection Approaches

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Abstract: Collecting in-vivo data from location-aware, augmented reality (AR) settings is challenging. This study explored the ecological validity of three data collection approaches, based on students' perceived intrusiveness and the assessment of the technical quality of the data. Eighteen 11th grade students participated in three conditions: (a) tablet-based audio recording, (b) researcher-led videotaping, and (c) head-mounted wearable cameras. Analyses showed that the action cameras hold more promise as a method for collecting data in AR settings.

Introduction

Location-aware augmented reality (AR) technologies have the capacity to immerse learners in authentic contexts (Dede, 2009), and as a result, can afford opportunities for situated learning and can contribute to students' motivation to learn. Collecting rich data in outdoor learning experiences allows researchers to gain enhanced understanding of the learning activity system, which, among others, includes the students, the technology, and the physical environment; this understanding is a critical contributor to an iterative design-based research cycle and to any evaluation effort. Along these benefits comes the methodological challenge of how to collect richer and more ecologically valid data to analyze students' discourse and actions. Reid, Hull, Clayton, Melamed, and Stenton (2011) discussed the following approaches for collecting data in AR settings: a) Questionnaires or interviews, b) Data logging and video, c) Think-aloud protocols and observational studies, and, d) Long-term, ethnographic studies. Retrospective data collection methods, such as questionnaires and interviews, can be inadequate for capturing the role of real-time, in-situ interaction that AR technologies can support. Similarly, think-aloud and observational studies can either distort the collected data or can miss important interactions. A combination of in-vivo data collection methods, such as data logging and video can better capture the temporal nature of the AR experience; however, video can, often times, be impractical (Reid et al., 2011) and notoriously difficult, as the unpredictability of physical movement and unforeseen environmental distractions make it extremely difficult to setup video equipment systems, such as cameras, tripods and microphones, to record visual data (Beck, Christiansen, & Kjeldskov, 2003; Zhang & Adipat, 2005).

The present study examined three approaches for collecting in-vivo data in augmented reality learning settings: (a) tablet-based audio recording, (b) researcher-led video recording, and (c) head-mounted action cameras. The questions of interest concerned the richness of the collected data, their validity and their technical quality. More specifically, the current study was guided by the following research questions:

(1) To what extent is each data collection approach intrusive for the participating students?

(2) How does each data collection approach compare in terms of the technical quality of the data it yields?

Methods

Eighteen 11th graders from an intact classroom of a suburban high school in Cyprus participated in this study. Students were of mixed abilities and their participation was voluntary; none of the students had any previous experience with location-aware AR learning technologies. Students, working in pairs (n=9), participated in a location-aware AR problem-based learning activity, hosted on the TraceReaders augmented reality platform developed by the first two authors. The AR activity asked students to investigate the sudden absences at a local elementary school, using data superimposed on the physical environment, such as videos, interviews, diagrams, and tables. Each pair was assigned to one of the three data collection conditions. In the first condition (n=3 pairs, audio recording), students' discourse was automatically audio-recorded by the app they were using only. In the second condition (n=3, video cameras), one research assistant followed each pair around at a distance of approximately two meters, capturing a third person perspective of the students' problem solving experience. Each pair was equipped with a lavalier microphone connected to the camera for capturing students' discourse. In the third condition (n=3 pairs, action cameras) students had head-mounted wearable cameras, which captured their efforts to solve the problem through a first person video perspective and audio recording. The researchers acted

as observers and provided technical support as needed. All students were informed that the app would automatically audio-record their discourse and log their actions on the tablet. The intervention lasted for an average of about 14 minutes. Data were collected via (1) the Intrusiveness Questionnaire, (2) three video-recorded focus groups, and (3) audio- and/or video-recordings of students in each of the three conditions and were analyzed using mixed methods. Intrusiveness was operationalized as the extent to which the data collection approach impacted students on a physical, psychological or learning-related level. The technical quality of the data was evaluated based on sound and image quality, the perspective of the data collection and the capacity of the collected data to enable the identification of the person talking.

Findings

The analyses of students' assessment of the intrusiveness of the data collection approach yielded statistically significant differences between the three groups (audio recording, researcher-led video, action cameras), $\chi^2_{(2,18)}$=6.35, p<0.05. Subsequent Mann-Whitney U test and Bonferroni correction tests indicated that these differences were statistically significant only between Condition 1 (audio recording) and Condition 2 (researcher-led video), with the students in Condition 2 reporting higher perception of intrusiveness (Mann-Whitney, $U_{(10)}$=3.50, z=-2.33, p=.015). The analysis of the focus group discussions confirmed the substantial differences among the three conditions, with Condition1 (audio recording) being perceived as of the lowest intrusiveness. In contrast, Condition 2 (researcher-led video) was perceived as of higher intrusiveness than action cameras.

Students in the audio recording condition did not discuss physical intrusiveness, probably because there was no external data collection equipment monitoring their activity. Students reported a low degree of learning-related intrusiveness, since, as they stated, they paid limited attention to the audio recording process, explaining that after the first minutes of the learning intervention, they had forgotten that their discussions were being recorded. The researcher-led video was mostly perceived as of high psychological and learning-related intrusiveness. Even though students provided no evidence about physical intrusiveness, psychological intrusiveness was high, as students said that this data collection approach made them feel exposed since they felt that their privacy was violated. Students also reported a high degree of learning-related intrusiveness, and did not feel free to express themselves. Finally, the action cameras data collection technique was mostly perceived as of low physical, psychological and learning-related intrusiveness. Most students reported that they felt comfortable with the action cameras on their head, indicating that the action cameras were light and, thus, caused no discomfort. Similarly, most of the students reported that the action cameras data collection approach was of low psychological intrusiveness, and perceived the action cameras as of low learning-related intrusiveness. The examination of the technical quality of the collected data in each condition (sound, image, perspective and identification of contribution) helped us identify the trade-offs of each data collection technique. While sound quality was sufficiently clear in all conditions, the lack of video in the audio-only condition did not help discern who was talking nor did it capture the students' interactions in the physical space.

The researcher-led camera included more of the surrounding context, whereas the action camera provided a first-person perspective. The video collected with the action cameras made it easier to identify learner's contributions (e.g. verbal contributions, handling of the tablet while in the field). This finding is crucial in the context of studying students' collaborative process in more detail, which is often a methodological challenge in the context of mobile computer-supported collaborative learning (Song, 2014). The findings from the present study also indicate that the action-cameras are a promising medium for collecting rich data in the field, as a seamless and low intrusiveness data collection approach. While continuing the search for less intrusive and more effective data collection methods, action cameras seem suitable for collecting in-vivo, digital video data in location-aware, mobile AR settings.

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Learning Progressions as Tools for Classroom Practice

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Abstract: We present preliminary results from a four-year, NSF-funded project in which we have engaged three departments of high school biology teachers in long-term professional development to support them as they develop, revise and enact formative assessments linked to a learning progression for natural selection. Reflecting on data collected between 2010 and 2014, we articulate our findings to date in three categories: formative assessment design, teacher formative assessment practice, and student learning.

Introduction

Research on learning progressions (LP's) in science specific content areas has influenced much of the work in education for the last decade, including standards initiatives, curriculum development, and assessment design (Cocoran, Mosher, & Rogat, 2009). In addition to being used for these purposes, some researchers have also argued that as representations of how student understanding builds within content areas, learning progressions may be useful in supporting teachers in their classroom assessment practices. These representations help teachers understand how core ideas and practices in science are related, as well as the common everyday ideas students bring to the classroom, and can then anticipate how to prepare elicit and respond to student ideas during instruction (Furtak, 2012; Bennett, 2011; Heritage et al., 2009). While LP's have been developed in recent years (see Duschl, Maeng & Sezen, 2011 for a summary), the ways in which they might support teachers in conducting and interpreting classroom assessments has not yet been fully explored, nor has the affect such a tool has on the discursive space been fully understood. This poster shares findings of a four-year, NSF-funded project in which we have engaged three intact departments of high school biology teachers in long-term, on-site professional development intended to support the design and enactment of formative assessments linked to a LP for natural selection in 10th grade general biology.

Theoretical framing

In this study, we take a situated view of teacher learning (Lave & Wenger, 1991) to explore how teachers from three different schools engage with a LP intended to support their formative assessment design and everyday assessment practices. The situated perspective "focuses on properties of activity systems, specifically on principles of coordination between the various components of such systems – the participants, the technological tools in the environment, and the informational structures and practices of the participants in the subject-matter domain of their activities" (Greeno, 2006, p. 87). We have drawn upon this framing not only to guide our design of teacher learning environments, but also to trace the development of teachers' practices as well as student's discursive engagement within the learning space. While prior definitions of formative assessment (FA) have delineated the tool as a series of steps in which a teacher elicits and responds to student thinking (e.g. NRC, 2001), we add participants to this as in Bennett's (2011) framing of formative assessment. In which the FA consists of a mediational network of practices and tools. As a *practice*, FA consists of the actions in which students and teachers engage, where ideas are made explicit in the learning space by the teacher, the teacher asks questions, responds to student ideas, and provides feedback to bring about student learning. When viewed as *tools*, formative assessments are the objects that create opportunities for students to share their thinking with their teacher and peers. Finally, the *participants* in FA are teachers and students, and formative assessment is most accurately conceived as requiring active participation of both.

Methodological approach

This study was longitudinal for teachers but not for students; that is, we have followed three departments of biology teachers for four years to explore changes in teachers' formative assessment practices and accompanying gains in student learning centered on the LP. However due to the structure of the school, the teacher had different students every year. The first year of the study began with data collection in which we videotaped teachers' existing instruction with no intervention during their normal natural selection sequence and administered pre-posttests regarding student understanding of natural selection. In subsequent years of the study, we have continued

to administer the pre-posttests and videotape classroom practices, but have also engaged teachers in monthly, on-site professional development meetings in which we situated teachers' work in their own classrooms and drew upon their knowledge and experiences to develop, enact, and revise a set of common FA's (Furtak, 2009). Our five-step professional development model begins with teachers *Reflecting* upon their current practice, sharing instructional strategies with each other and discussing advantages and disadvantages. In the second step teachers *Explore Student Ideas* as well their own understandings of the content at hand using the learning progression. In the third step, teachers *Develop Tools* for students to make their ideas public. In the fourth step, teachers *Practice* using FA's, categorizing samples of student work, and anticipating feedback, using the learning progression to help them anticipate how students might respond to the assessment they have developed. The fifth step has the teachers *Enact* their assessments, after which they complete the first iteration of the cycle by *Reflecting* upon their enactment and revising the assessments. We have videotaped all classroom enactments and all professional development meetings for these analyses.

Preliminary findings

We articulate our findings in three categories: formative assessment design, teacher formative assessment practice, and student learning. With respect to *design of formative assessment tools*, we have found that, during each year of the study, teachers at all three schools have taken the learning progression as an opportunity to re-sequence their instructional units and to actively coordinate their work in developing, enacting, and revising formative assessments (Furtak, 2012). With respect to *formative assessment practices* we have observed changes in the amount of time teachers give to eliciting and attending to student thinking, an expansion in the repertoire of strategies teachers use to enact formative assessments, and an increase in student voice and the overall discursive space. Finally, with respect to *student learning*, we have found that within-year effect sizes have increased at all three schools from the baseline year of the study to the third year of data collection. Taken together, we estimated the relationship among teachers' formative assessment abilities and student achievement through an ANCOVA comparing the two cohorts of students participating in the study, and two Hierarchal Linear Models that estimated the contribution of each of the FA variables to students' posttest scores in the baseline and year 3. These sets of results represent a clear improvement in teachers' FA tool design and classroom practice, accompanying increases in student learning, and shifts in discourse.

Significance and relevance to conference theme

The results of this project are the first of their kind in the field; namely, the first attempt to trace the influence of learning progressions on teacher practice, student performance and discursive space over multiple years. This work is essential to better understand the ways that teachers come to use these tools in their instruction and their relationship to student learning given the reliance upon the *Next Generation Science Standards* in design. The project's design and focus on teachers' reflective practices in order to shift the development of discursive space towards students through formative assessment, is directly related to the conference theme of *Transforming Learning, Empowering Learners.*

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A Tri-Level Partnership to Support and Spread Knowledge Building in Ontario

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Abstract: This paper describes a school-university-government partnership to develop capacity for Knowledge Building/knowledge creation throughout Ontario. The work can be framed as a collaborative effort to transform schools into *knowledge creating organizations.* The spread of Knowledge Building in schools and districts has exceeded expectations. Ongoing evaluation of this work contributes to an understanding of collaborative practice to foster innovation in education.

Keywords: Knowledge Building, networked communities, professional learning

Introduction

Ontario is recognized as a global leader in education, with one of the highest performing school systems in the world. In the McKinsey report, Ontario is recognized as a "sustained improver" (Mourshed, Chinezi, & Barber, 2010, p. 11)—a system with a distributed rather than centralized model to engage schools, teachers and administrators in responsibility for developing and implementing effective instructional practice grounded in innovation and collaboration (p. 20). This trajectory of system improvement "is all about turning schools into learning organizations" (p. 111).

The research to be reported describes a coordinated effort to support continual innovation in Ontario. It focuses on a unique partnership between school, university, and government representatives to develop capacity for Knowledge Building and knowledge creation (Scardamalia & Bereiter, 2006), with spread throughout the province. Knowledge Building is "an attempt to refashion education in a fundamental way, so that it becomes a coherent effort to initiate students into a knowledge creating culture" (Scardamalia & Bereiter, 2006, p. 97). In terms of a trajectory of system improvement, the work can be framed as a collaborative effort to transform schools into *knowledge creating organizations.*

Multi-institutional partnerships for Knowledge Building

School-university-government partnerships are a powerful mechanism for spreading Knowledge Building within a system (Laferriere, Montane, Gros, Alvarez, Bernaus, Allaire, Hamel, & Lamon, 2010). This work represents the first attempt to create a scalable model for Knowledge Building in Ontario. The partnership involves three Principals' Associations: the Ontario Principals' Council (OPC), the Catholic Principals' Council | Ontario (CPCO), and l'Association des directions et directions adjointes des écoles franco-ontariennes (ADFO). Another partner is the Institute for Knowledge Innovation and Technology (IKIT) at the Ontario Institute for Studies in Education (OISE), University of Toronto. Finally, the Ministry of Education, Student Achievement Division, is represented by members of the Literacy and Numeracy Secretariat (LNS) and the Research, Evaluation and Capacity Building branch. This tri-level partnership advances two major Knowledge Building projects: the "Knowledge Building Initiative," embedded within the Principals' Associations' Leading Student Achievement: Networks for Learning (LSA) project, and the "Tri-Board Knowledge Building" project. The projects share the objectives to support professional leadership and learning relating to the twelve principles of Knowledge Building (Scardamalia, 2002), and to introduce Knowledge Forum, which is technology designed to support knowledge building processes.

Methodological approach: Building capacity for Knowledge Building in Ontario

The Leading Student Achievement: Networks for Learning (LSA) project is developed by the Ontario Principals Associations, in partnership with the Ministry of Education. The project is guided by the evolving "LSA Theory of Action" framework, designed to help cultivate leadership that positively influences four key conditions that have direct and indirect effects on students (Leithwood, 2012). Work on the Knowledge Building initiative in 2013-2014 led to the development of "A Knowledge Building Theory of Action for LSA" (see Leithwood, Jantzi

& Slater, 2014), which illustrates the importance of the Knowledge Building principles and their influence on key learning conditions (see Figure 1). Recent research focused on exploring characteristics of effective networks to inform the project has resulted in a model of network effectiveness for LSA (Leithwood, Azah, & Jantzi, 2015) aligned with these principles.
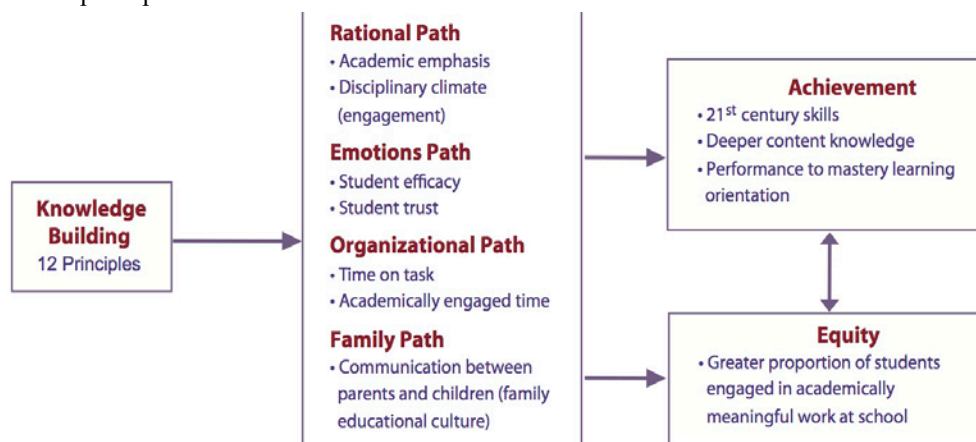
Figure 1. A "Knowledge Building Theory of Action for LSA."

Findings and discussion

In as little as two years, at least 54 schools spanning approximately 15 districts have become involved. Participants attribute the success of the work to three main factors: grassroots, voluntary nature of the work; rigorous pedagogical principles that can deepen work in classrooms and professional learning; and alignment of Knowledge Building with existing school and board goals. Formal assessments are being developed to verify these informal findings. In addition, Ministry and LSA representatives have reported three common trends from qualitative observations of project participants: high engagement and excitement; sharing ideas; and school-wide spread (see Shaw et al., 2014). A cross-board analysis conducted for the TriBoard project (see Ministry of Education, 2014) reported enhanced professional and student learning, a demand for continued professional learning, and the need for administrator involvement (see Ministry of Education, 2014). Additionally, participants in the LSA project reported broad engagement with the Knowledge Building principles: *real ideas, authentic problems*; *epistemic agency; improvable ideas*; *concurrent, embedded, and transformative assessment* (Leithwood, et al., 2015), as well as positive effects on student problem solving skills, depth and complexity of idea development, and willingness to collaborate (Leithwood et al., 2015). Ongoing evaluation of the work can contribute to an understanding of networked practice to support innovation in education.

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Building Sustained, Knowledge Creating Networks in Education

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Abstract: Collaborative innovation networks can serve as drivers of system improvement in education. This paper describes a multi-institutional pilot project focused on the development of multi-level networked design communities consisting of students, teachers, principals, and policy makers, dedicated to sustained knowledge creation. These networked communities are responding to the need to advance achievement in literacy and numeracy in Ontario, as well as creating hubs of innovation that can produce research-based pedagogical innovations to spread throughout a provincial network.

Keywords: Knowledge Building, collaborative practice, innovation networks

Introduction

In high-performing educational systems, networked environments have helped to shift "the drive for change" from a centrist to a distributed model in which schools can engage in innovation and "self-sustaining" improvement (Mourshed, Chinezi, & Barber, 2010, p. 22). However, the establishment of networks does not guarantee effective practice or innovation (Hargreaves, 2004). Very often, the cultural norm at the school level is implementation rather than innovation. Hargreaves (2004) argues for the development of "innovative educational networks" that place knowledge creation and innovation at the centre as a means to enable educational systems to remain on a trajectory of continual improvement. So, *how can we build sustained, knowledge creation networks in education?* This paper describes a multi-institutional pilot project that will experiment with the development of a design community consisting of educator and student networks dedicated to sustained knowledge creation. Designs represent a response to the need to produce innovations that will help advance achievement in literacy and numeracy across the curriculum in Ontario. The proposed work adopts a "Knowledge Building" (Scardmalia & Bereiter, 2006) approach, which engages learners directly in the kind of knowledge creation that goes on in innovative organizations. The project engages and supports schools willing to operate as networked hubs with Knowledge Building/knowledge creation as a core practice.

Project background

A unique school-university-government partnership in Ontario provides the context for this work. The partnership includes the Ministry of Education, the Ontario Principals' Council (OPC), the Catholic Principals' Council | Ontario (CPCO), and l'Association des directions et directions adjointes des écoles franco-ontariennes (ADFO), and the Institute for Knowledge Innovation and Technology (IKIT), at the Ontario Institute for Studies in Education (OISE), University of Toronto. The partnership was created in 2013 to advance the "Knowledge Building Initiative" within the Leading Student Achievement: Networks for Learning project, and the "Tri-Board Knowledge Building" project.

Characteristics of innovative networks

Literature on Knowledge Building, as well as "Collaborative Innovation Networks," or COINS (Gloor, 2005) informs a framework for characterizing an effective knowledge creation network. Knowledge Building is "an attempt to refashion education in a fundamental way, so that it becomes a coherent effort to initiate [learners] into a knowledge creating culture" (Scardamalia & Bereiter, 2006, p. 97). Knowledge Building is grounded in twelve foundational principles that are drivers of innovation and creativity (Scardamalia, 2002), such as *idea diversity*, *idea improvement*, and *community knowledge, collective responsibility*. These principles, when enacted in networked environments, support "collaborative innovation networks," or COINS, as defined by Peter Gloor (2005). COINs are defined as "a group of self-motivated people with a collective vision, enabled by the web, to collaborate in achieving a common goal by sharing ideas, information and work" (Gloor, Heckman, & Makedon, 2004, p. 2). They have been described as "the most productive engines of innovation ever" (p. 10). In a study exploring the nature of COIN interactions, Gloor and Fronzetti (2015) identified "six honest signals of

communications" that were "excellent predictors" of organizational creativity and performance, including balanced contribution, honest sentiment, innovative language, central leaders, rotating leadership, and rapid response. A study exploring leadership patterns in a grade four Knowledge Building class found a decentralized structure as well as evidence of "rotating leadership" in the student network (Ma, Matsuzawa, Kici, & Scardamalia, 2015), suggesting similar "signals" as emergent phenomenon of Knowledge Building and COINS.

Developing innovative knowledge creating networks in education

The proposed research begins with the development of educator and student networks committed to operating as a Knowledge Building community. The work represents a communal effort to translate Knowledge Building principles into markers of innovation networks, with both student and educator participants monitoring these markers to determine how to improve the Knowledge Building practices going on in the school. In this sense, the school community would function as a "networked improvement community," or NIC, using *practice-based evidence* to inform goals and help set the trajectory of improvement through iterative cycles of testing and refinement (Bryk, 2014). New digital technology will play an essential role both in enabling classroom and school-wide knowledge creation and in enabling automatic, non-intrusive assessment of group and individual performance. Targeted feedback would provide visualizations—powerful formative feedback based on social and semantic network analysis—to characterize community interactions and idea improvement and engage educators and students in progressively shaping collaborative Knowledge Building activities.

Discussion

The exploratory research reported here has served to uncover significant issues and factors relevant to the development of collaborative Knowledge Building networks to support the improvement of ideas within and between classrooms. Preliminary baseline data in the form of annual student surveys demonstrate changes in the school community dynamics. For example, in the time span before Knowledge Building work was incorporated to two years later there was over a 50% increase in students who reported that they "like their school work" and "enjoy coming to school" (Nichols & Gallagher, 2016). These findings suggest that "bringing to life" Knowledge Building principles such as *community knowledge* and *epistemic agency* results in greater motivation for knowledge work. This research is leading to targeted automated assessments to demonstrate multiple principles/markers of innovation and change over time. Further, early descriptive research is providing data to inform large-scale research involving approximately 60 classrooms across multiple school boards—a study designed to demonstrate the power of networked environments with formative feedback to students, teachers, and principals to foster sustained collaborative innovation.

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Structuring Authentic Open Inquiry in an Undergraduate Science Lab Course as an Epistemic Onramp to Professional Physics

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Abstract: This study reports on the challenges of implementing an open-ended, learner-centered laboratory curriculum into undergraduate science education. The research team sought to document the course's "curricular activity system" (Roschelle, Knudsen, & Hegedus, 2010) to develop a framework that would allow other faculty to more easily structure their own similar laboratory courses. With a focus on the facilitation of learning through peer-based review and feedback, we closely examined the role of instructional moves and technical infrastructures in supporting undergraduate students' authentic experimental science research activities. Findings reveal that students in the class participated in a full spectrum of practices identified with professional physics, even if at only a preliminary level. Subsequent interviews with students working in research labs indicated that students attribute some of their preparation for professional practice to the open-inquiry course (Holmes, in progress).

Keywords: open-inquiry, science education, practice, epistemology

Introduction

Over the past few decades, science education research has promoted a significant pedagogical shift away from much-criticized transmissionist models of instruction in favor of models that facilitate students' participation in authentic scientific practices. These practices, by and large, revolve around the design and investigation of scientific inquiry, and include: generating questions, designing experiments, collecting/organizing data, communicating findings, and arguing/debating explanations (NRC, 1996, 2015). While open-ended inquiry projects are not necessarily novel in the arena of K-12 science education, undergraduate laboratory courses typically offer few opportunities for students to take over epistemic and logistic authority, or in other words, to "own" the learning process.

Indeed, undergraduate science labs overwhelmingly follow a "cookbook" structure that organizes activities around verifying lecture material or well-established scientific knowns. Scholars argue that typical lab activities fail to engage students in the cognitively challenging kinds of tasks and practices that underlie authentic scientific research (NRC, 2015; Roth, 1994). Hence, the purpose of science laboratory work is misrepresented to undergraduate students who, as Hofstein and Lunetta (2006) state, "perceive that the principal purpose of a laboratory investigation is either *following the instructions* or *getting the right answer*" (p.38 emphasis in original). An important instructional challenge, therefore, is creating learning opportunities that appropriately represent and orient students to scientific epistemologies and practices. Such opportunities can shift student experience of "what counts" as learning (i.e., grades or experiences) and prepare them for future scientific research.

Background of the research

The purpose of this project was to produce a scalable model for open-ended laboratory curriculum that could be implemented by interested faculty at a large university in the western United States. The research team undertook an effort to document the course's "curricular activity system" (Roschelle et al., 2010) to help with the development of a framework that would allow other faculty to more easily structure their own similar laboratory courses. By invoking Roschelle et al.'s notion of a design object that encapsulates a learning progression (curriculum), the key materials, participant roles, and tools used to achieve a shared goal (activity), and related design components that support the learning activities (system), we sought to identify the curriculum supports (technical and otherwise) that would help guide instructors implement inquiry-based, authentic science reforms in undergraduate classes.

Methods

Data sources for this study included observational field notes from two sections of an advanced introductory-level physics laboratory course that met each week over a ten-week academic quarter. Researchers observed 17 individual class meetings, documenting students' interactions with the teacher, other students, and laboratory

materials while small groups of students worked collectively on open-inquiry projects. Over the ten-week period, students worked on two successive assignments, each involving the design and execution of a research project related to projectile motion and rocketry. As mentioned above, projects entailed a full range of scientific activities, but focused strongly on the development of interesting (yet answerable) research questions, reliable and consistent measurement instruments, and sound analytical methods to get at the guiding research questions. Using the Cognitive Task Analysis of Experimental Science (CTAES) to help guide our coding, we categorized observations of students' interactions and scientific activities according to practices described in the CTAES. From this round of coding, we constructed a "trajectory map" to visualize patterns in students' scientific practices across the ten weeks, as well as to identify infrastructural and pedagogical supports that undergraduates and laboratory course instructors need to engage in similar long-range, open-inquiry activities. We also were able to compare the organization and sequencing of student activities with the tasks in the CTAES. Finally, interviews conducted by a collaborating researcher for a study on undergraduates' participation in professional research activities shed further light on the distal outcomes of the inquiry lab experience.

Preliminary findings and discussion

Early analysis of the observational data indicates that the students in this study spent a majority of the inquiry process (i.e., experimental design, data collection, analysis, and presentation) testing and refining research questions, and collecting data on the performance of their constructed apparatuses and the apparatuses' constituent parts. Whereas traditional cookbook laboratory experiments do not provide students sufficient time or means for such practices, we found this aspect of open-inquiry essential to the process of developing students' scientific intuitions, as well to their epistemic framing of what counts as "doing science." Moreover, when compared to the full range of activities specified in the CTAES, students engaged in *all* of them – although some, such as "develop[ing] procedures for tracking down the source of malfunction when the individual components or the assembled apparatus do not perform as designed" in only preliminary or preparatory ways. Despite skepticism expressed by some faculty in the department that students would be able to develop questions and design and conduct experiments to address those questions, students organized themselves to appropriately engage with the disciplinary practices, discourse, and content such that they experienced at least precursory aspects of the full arc of scientific inquiry and referred to these experiences later when in a professional research lab. These findings suggest the possibility of assessing student learning more directly in terms of the on-ramps to professional practice designed into the learning environments (Rupp, Gushta, Mislevy & Shaffer, 2010). Ultimately, the most important outcome of this work is documenting in detail the relationship between the curricular activity system built by the instructional team in order to provide explicit guidance to other instructors so that they can also support the types of outcomes we have observed.

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From Classroom Interaction to Clinical Reasoning: An Interactional Ethnography of PBL in Speech and Hearing Sciences

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Abstract: The aim of this study was to examine how PBL sessions in an undergraduate PBL curriculum are consequential to clinical reasoning. An Interactional Ethnographic (IE) logic of inquiry guided collection and analysis of video recordings and learning artefacts. The 3rd Year enacted decision not to include oral motor exercises was evident in the intended curriculum disciplinary knowledge frames viz 'functional' and 'organic' sound production found in 2nd Year archived PBL case materials and discussions.

Introduction

In terms of scale, units of analysis for interactional studies in higher education are typically confined to a series of sessions/ classes and, in even fewer cases, at the unit of course (8-10 weeks). Whilst problem-based learning (PBL) is often researched at this level, there is potential for analysis at larger scale in cases where the entire curriculum is designed using principles of PBL (Lu, Bridges, & Hmelo-Silver, 2014; Bridges, 2015). Discourse-based analysis of PBL facilitation (Hmelo-Silver & Barrows, 2006) has identified the explicit goal of medical facilitators in linking the PBL problem to the clinical reasoning process. Using an Interactional Ethnographic (IE) approach, this study examined the consequential nature of knowledge building across key learning contexts and events (PBL sessions and clinical tutorials) across 2 years within a 5-year undergraduate PBL program in Speech Language Pathology. A specific interest was to investigate local rationality in terms of what 'counts' as curricular experiences (Heap, 1990). The study's aim was to examine how reasoning processes developed in technology-rich PBL environments in the earlier years of undergraduate curricula are consequential to case-based reasoning during clinical tutorials in later years. This builds on prior ethnomethodological research in computer-supported collaborative learning identifying, for example, the use of 'respecification' (Zemel & Koschmann, 2013). The research question was: *How do the multiple members of the PBL learning community draw upon evidence within and across curriculum contexts, specifically from PBL tutorials to case-based clinical discussions?*

Methods

As part of a larger, nationally-funded research on PBL in health sciences, this case study examines PBL enactment in a fully integrated 5-Year BSC(SPEECH) curriculum in Hong Kong. All students participate in small group PBL tutorials, led by a trained facilitator, and complemented by skills laboratories during which clinical skills are taught and practiced in Years 2-4. All students complete clinical practicums in Years 3-5. In Year 3, students first complete 16 weeks of PBL tutorials and are then placed in a clinical group of 6 students. Each student provides assessment and therapy to one to two children and engages in group case discussions. An IE was conducted to structure and manage data collection aimed at exploring key interplays between intended and enacted curriculum (Porter, 2006). Ethical approval and participant consent were gained for data collection from facilitators and students in Years 2-3. The data archive includes artefacts (case materials, group notes composed collaboratively on the IWB) and video recordings of 2nd Year PBL (19 tutorials) to 3rd Year clinical sessions (20 sessions).

Analysis

The starting point of analysis was the identification of treatment decisions proposed by students during 3rd Year clinical tutorials and to map the knowledge base to earlier PBL cases, classroom artefacts and knowledge building discourse. The anchor point for the analysis presented are two 3rd Year 'telling' cases presented within a clinical debriefing and planning session focusing on two children with speech sound disorders. Analysis of intertextual ties traced learning issues linked to knowledge frames regarding speech production from the 3rd Year clinical discussion and the archived case of a 2nd Year PBL case materials, classroom artefacts, and student discussion addressing foundational learning topics (see Figure 1). The 'telling case' (Mitchell, 1994) of Case 4 illustrates the tracing of knowledge across events and over time at different level of analytic scale using Case 4 as a telling case to make visible the approach.

Findings

Figure 1 traces the application of disciplinary knowledge frames viz 'functional' and 'organic' types of speech sound disorders which impacted on the students' clinical decision making in assessment and ongoing treatment planning. From an intended curriculum perspective, the 3rd Year enacted decision not to include oral motor exercises and focus on tone can be traced back to the archived 2nd Year PBL discussion collaborative notes about normal speech sound development and speech sound disorders synthesized via an IWB. The cleft palate case indicated students were considering how structural characteristics of the articulatory and resonance system affect their speech production.

Backward mapping between textual 'anchor points' in 2nd Year PBL and 3rd Year Clinical cases			
BSC(SPEECH)			
2nd Year PBL Case scenarios (recorded n=4)		Year 3 Clinical cases (recorded n=12) Developmental speech & language disorders in children	
Problem #10: Cleft Palate Case		Telling Case #4: Speech & language disorders in children	
Case artefacts & discussions		Tutorial 1	Tutorial 2
PBL knowledge building focus: • Normal speech sound development • Functional and organic speech sound disorders	Group notes (via IWB): • Clinicians should help people with cleft palate to articulate with correct manner and place of articulation. No oral motor exercises should be used. • Nasal emission in people with cleft palate affects their production of pressure consonants (plosives and fricatives)	"The first priority would be *tone acquisition* because it affects the intelligibility for a lot … She's a bit *overbite at the lower jaw* but I'm not sure how it affects her articulation. Yeah, I wanna *assess the tones* a bit further….to see if she responds to certain cues and, for example, visual cues."	"Today I assessed the stimulability of my client (.) er about her tone and some vowel errors, and also I started to *treat her tone* too. I found that she can respond to the verbal cues and visual cues, hmm but not very consistently. I think still the *tones and vowel error* would be my main focus."

Figure 1. Event Map

Conclusions and implications

Application of an IE approach enabled 'backward mapping' of the references to prior events, to particular actions, ways of talking about the phenomena, and uses of clinical terminology as it was being constructed in the moment-to-moment interactions. The recursive, iterative process made visible the curricular origins of disciplinary knowledge as constructed by the actors *in situ* and overtime not as a product but as a process of construction. This logic stays constant so we can trace the 'discursive roots' applied to solve the present clinical problem (prior instances of the same terms, actions or processes in use as signaled in past tense and direct & intervisual references or descriptions) and curricular routes (how we look across the years of the planned and co-constructed curriculum) and how these are interactionally accomplished in the moment-by-moment coordinated actions and talk of the actors in a PBL curriculum design. Also indicated was the potentially consequential effect on case discussions in senior years of the shared, large-screen visualizations using an IWB to construct multimodal collaborative PBL notes. By tracing knowledge construction across contexts, the IE approach enabled identification of the trajectories of productive disciplinary engagement and technologies as preparation for professional practice. Indeed, the goal of PBL is to engender this in many ways and so the argument holds that one would expect this to occur in greater depth over the years of the curriculum. Analysis of excerpts of classroom discourse indicated that at later years of the more senior students were engaging with ideas at deeper levels and displaying more sophisticated reasoning processes later in the curriculum. As Engle & Conant (2002) argued, productive disciplinary engagement is attained though creating environments (problematizing, authority, accountability, resources) that not only account for agency but also collaboration. In the classroom discourse, undergraduates were seen to be accountable to each other as collaborative learners as well as to the disciplinary norms, especially when formulating clinical judgments. Implications are evident for more longitudinal discourse-based PBL studies across contexts.

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Acknowledgements

The Redesign of an Extensive Learning Environment for Medical Education

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Abstract: This paper documents and explores the rationale and methodology underlying the user interface and experience redesign of a medical training program intended for internal medicine doctors preparing for their licensing certification. Specifically, it considers how principles of effective instruction such as content *interleaving* and *spacing* may be incorporated into the design of complex learning environments that contain content that requires months, if not years for users to learn.

Keywords: design, medical education, extensive learning environments, interleaving, spacing

Introduction

This paper—a collaboration between academia and industry—presents a case study of ongoing efforts made in the context of a large-scale redesign of a medical training program. So doing, we hope to illustrate how notions such as "transforming learning, empowering learners" play out in the wild.

The case of medical education

Internal medicine doctors in the USA are required to pass certification exams in order to receive and renew their license to practice. The average time spent preparing for the exam is measured in months. Historically, doctors have relied upon self-study using traditional media such as recordings of lectures, flash cards, and textbooks. We use the term *extensive learning environment* (ELE) to differentiate interactive learning environments wherein a lengthy investment of time (months, years) is required to develop a deep understanding of some subject matter.

Applying theory to design practice

The research conducted to date on both *spacing* and *interleaving* (Brown, Roediger, & McDaniel, 2014) were deemed compelling enough to incorporate into the redesign of an extensive learning environment for internal medicine education. The principle of spacing concerns the accepted wisdom that studying in small increments over a period of time is more effective than cramming large amounts of information in a shorter duration. The principle of interleaving, as opposed to block sequencing, refers to the order in which related ideas are taught.

This paper will explore how these two principles of effective instruction were ultimately incorporated into a revised mobile-based design. An added contribution of this paper will be a methodological examination illustrating how theory of learning and user-centered techniques can reflexively inform the redesign of an ELE.

Overview of the design problem

In order to fulfill medical certification requirements, internal medicine doctors must successfully complete a comprehensive examination spanning 17 content areas. Because internal medicine doctors are tasked with helping other doctors diagnose both common and difficult to identify illnesses, they must be prepared to encounter patients presenting a wide spectrum of symptoms. In order to receive a passing score, a doctor should expect to correctly answer close to 200 out of approximately 240 questions. Exam questions are presented in the form of short and long form clinical narratives, wherein the doctor must select a correct diagnosis from a multiple-choice list based on the information presented. Given that up to 15% of all test-takers will not successfully pass their certification exam in a given year and therefore become at risk of not being able to practice medicine, the examination is considered extremely high stakes. Most prospective test-takers invest several months of preparation for the exam, which can only be taken once each calendar year.

Limitations of the previous design

The initial version of the ELE utilized a desktop web-browser interface. In short, the program was only somewhat more sophisticated than a set of flashcards with explanations instantiated in digital format. While seemingly adequate as a study aide (we record 100,000+ study sessions to date), the research and design team decided that a rethinking of the application's design was required in order to better meet the learning needs of users.

Methodology behind the redesign

The process of redesigning the ELE began with reexamining the content to be learned as well the context for application. According to official exam blue print, doctors would be provided a total 8 hours to complete an exam of approximately 240 items. Therefore, a secondary objective would be to train doctors to answer at an average rate of 2 minutes per question.

The next step in our design process was to develop user personas (see Pruitt & Grudin, 2003) through a combination of interviews, surveys, and information gleaned from online forums dedicated to studying for the certification examination. We learned that internists preparing for the exam were either in the process of completing residency/fellowships, or already working fulltime positions in hospitals (a requirement for keeping the job is passing the examination). As a result, most reported finding it extremely challenging to allocate adequate preparation time.

Finally, we enlisted the aid of "naïve" experts, individuals with expertise in either educational theory or UI/UX design but no prior experience using our original application, in order to generate fresh insights and critiques about our application that we might otherwise be blind to.

Rationales and the redesign

As previously noted, three overarching themes became the driving impetus for the redesign of the ELE: (1) respecting users' time; (2) a structure of interleaving and spacing; and (3) simplifying user interface/experience.

Respect for time

The original incarnation of the ELE allowed users to select the topics they wanted to study. Each topic had a fixed number of questions. Users would then work through however many questions they had selected.

In the new incarnation of the ELE, users instead determined how much time they wished to allot to a brief study session. The program would then allocate a fixed number of problems based on the desired answering rate of 2-minutes per question.

Structured interleaving and spacing

Given that our database of questions and answers includes close to 1600 items, it was perhaps to be expected that users attempting to master said items would utilize a block based approach (topic by topic) in order to organize and make sense of the material.

In order to simultaneously provide some manageable structure while respecting our desired principles, we chose to divide our corpus of problems into 16 groups of 100 items each. Each group contained a representative distribution of items across all 17 content areas as indicated by the official exam blueprint. For example, a topic such as cardiovascular disease which comprises 14% of the actual exam, would appear roughly 14 times per group.

Simplifying user interface and experience

The overall flow of our current ELE can be summarized as follows: A user picks a desired time of study and is presented a series of questions. Users *cannot* control the order of questions, or the content matter of said questions. The program allocates the questions in predetermined groups of 100 items. Users progress through each group of 100 at their own pace, and may review groups that they have already completed.

Concluding remarks and future work

As the content being presented in computational learning environments continues to become increasingly complex, we believe that the need to identify and adhere to organizing principles of both user interface *as well as* cognitive interaction design will only become increasingly essential towards maximizing the utility and effectiveness of said environments for learners. We have attempted to provide readers with a brief peek "under the hood" of how a large-scale for-profit business makes use of academic research to transform learning and, we hope, empower learners. Presently, we are conducting small-scale usability studies before rolling out the revised product to our user base. Future work will involve data analyses comparing the effectiveness of our structured interleaving solution to the original design. We look forward to sharing this data at a future conference.

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How Do Learners With Different Epistemic Beliefs and Needs for Closure Approach Instructor's Feedback to Project?

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Abstract: Instructor's feedback is essential in project-based learning, yet learners approach feedback differently. This study examined how learners with different *epistemic beliefs (EB)* and *need of closure (NFC)* profiles responded to instructor's feedback in a multistage course project, and found that EB interacted with NFC to influence learners' handling of feedback.

Introduction

Research on feedback has mostly focused on the effects of feedback rather than student processes and responses to feedback, especially in project-based learning (Hattie & Timperley, 2007). Feedback may not have a universal effect on learners. This study investigated how learners with different *epistemic beliefs* (EB) and *need for closure* (NFC) profiles responded to instructor's formative feedback in a multistage course project.

EB represents individuals' beliefs about the nature of knowledge and knowing (Hofer, 2000). An individual with naïve EB would consider knowledge as isolated pieces, while a person with sophisticated EB may believe knowledge as complex and interrelated. The role of EB in education has been examined (e.g., DeBacker & Crowson, 2006), yet research to date has not investigated how EB might influence learners' handling of feedback, although Butler and Winne (1995) posited that EB may act as a filter that affects how students interpret and handle feedback.

NFC refers to learners' willingness or reluctance to grapple with information (DeBacker & Crowson, 2009). High desires to reach closure are manifested in *seizing* (arriving at a quick solution or using superficial processing) and *freezing* (protection of prior knowledge or established solutions with only superficial scrutiny of new information) (Kruglanski & Webster, 1996). NFC is connected to achievement goals, cognitive engagement and grades, and also correlated with EB (DeBacker & Crowson, 2006, 2008). Research to date has not investigated how NFC or its interaction with EB influences learners' handling of feedback.

Methods

The study was conducted in an instructional technology course at a Southern U.S. university. Students engaged in a semester-long project to design a training website for a target learner group. The project had four progressive milestones with required deliverables. The instructor provided feedback to each milestone, and students were required to submit a response to summarize and discuss plans to address the feedback.

Participants completed the discipline-focused epistemic beliefs (Hofer, 2000) and the need for closure (Roets & Van Hiel, 2011) questionnaires at the end of the semester. Purposive sampling identified four students with different EB and NFC profiles. Data sources included the students' responses to the instructor's feedback, and their end-of-semester written reflections on the instructor's feedback. The findings below summarize the patterns each student demonstrated in their responses to the feedback over all the four milestones.

Findings

Case 1: Mickey – Sophisticated EB, low NFC

Mickey's responses were long. He not only itemized and identified all the issues in feedback but also showed genuine understanding and internalization in reiteration of the issues in his own words and discussions about the reason for improvement. He reflected, "When reviewing feedback I would make sure to … look back at what we had originally done." His resolutions of issues showed thoroughness and clear linkage to feedback. He elaborated goals and plan for improvement, often with substantial revision work. Feedback helped him to "think of different ways," and to bring "attention to gaps that we looked over and areas that we thought were fine."

Case 2: Cary – Sophisticated EB, high NFC

Cary's responses were much shorter than Mickey's. He identified the issues in feedback only at a general level, while ignoring many details. For the issues he chose to attend to, he showed a decent understanding yet lacked the sign that he internalized the issues, e.g., describing why improvement was needed. Cary's resolutions of issues

were limited to selected ones. His plan for improvement did have some elaboration and show alignment with the issues, but no actual revision work was included. He perceived feedback as the offering of another perspective and a time saver, "Paying attention to feedback ahead of time will save you in the long run."

Case 3: Chris – Naïve EB, low NFC

Chris's responses were short like Cary's. He went straight to resolution without identification of issues. Like Cary, he chose to address limited issues. His resolutions often showed a lack of understanding of the issues. He would spend some length discussing his plans which often lacked alignment with the issues, and tended to fixate on a direction with much detail of little relevance. Chris perceived feedback as valuable to an effective result.

Case 4: Mable – Naïve EB, high NFC

Mable's responses were the longest. Like Mickey, she identified and itemized all the issues in the feedback. However, her responses focused more on actions than on elaboration and internalization of issues. At times, her resolutions showed a surface understanding of issues. Her resolutions attempted to address all the issues, with sufficient details and often substantial work. Some revisions appeared to be a rush to action with an incomplete or simplified understanding of the issues. Mable regarded feedback as the instructor's perceptions of their work.

Conclusions and future work

The current study examined how students with various levels of EB and NFC responded to instructor's feedback. For the two students with sophisticated EB, the one with low NFC responded to feedback better than did the other with high NFC, whereas for the two with naïve EB, the one with high NFC fared better than did the peer with low NFC. The differential effects of NFC at different EB levels make it interesting to investigate how EB interacts with NFC to influence students' responses to feedback, so that feedback can be more effectively used as a scaffolding tool. Future studies can focus on feedback on tasks with high complexity, since NFC is more pronounced in dealing with complex issues. Finally, examining learners' actual project performance can provide further insight into the influence mechanism of EB and NFC through feedback.

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Augmenting Learning From Physical Museum Exhibits With Personal Mobile Technology

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Abstract: This paper reports a study to improve users' experiences in a visitor centre by incorporating a mobile scanning visual recognition system, called Artcodes. A prototype mobile treasure hunt guide was developed and evaluated by means of a field study comparing this technology with the existing personal guided tour. The results reveal a preference for the mobile guide among participants and show significant learning gains from pre-test to post-test compared with the existing personal tour.

Introduction

In this paper we address the problem of supporting collaborative and inter-generational informal learning during museum visits by means of a mobile treasure hunt by integrating elements of augmented reality (AR) and games into the experience. More specifically, we report the design and analysis of a field trial with the mobile application designed to provide an integrated physical-digital experience in a visitors' centre focused on the science, art and design of local cultural artefacts – Malaysia's Royal Selangor Visitor Centre. Since a large number of visitors to the centre are children, our design targeted families with young children and school groups. We adopted the theme of the "Science of Pewter" to explore ways in which the visual recognition technology and design of the mobile experience can enhance visitor's knowledge and experience. One of the guiding principles for our research included applying the concept of 'trajectories' (Benford et al., 2009) which encourages the designers of visiting experiences to consider the following key phases: approach, engage, experience, reflect and disengage. Figure 1 shows a detailed example of the trajectory for one of the exhibits.

Our technological approach has been to work with Artcodes, a visual recognition technology first reported in Meese et al. (2013). We chose this particular approach because it enables skilled graphic designers to draw their own interactive images from scratch by following a set of simple topological rules. We carried out an initial experiment applying Artcodes to pewter, since it is a malleable metal alloy, ideal for crafting decorative or specialty items. Early testing revealed challenges for applying Artcodes to pewter which include the effects of variable environmental lighting, and specular reflections from the shiny material.

More specifically, our research questions were: 1) How do we design the experience to foster greater social interaction and collaboration between team members? 2) Is the scanning technology usable in a real world setting and 3) Can it contribute to learning about the exhibits?

Method

The main user trial involved groups comprising families with their children and teachers with schoolchildren. We employed pre- and post-experience questionnaires in a comparative study between two types of tour: the mobile treasure hunt (experimental condition) and personal guided tours given by Royal Selangor staff as with existing practice (control condition). The post-test survey consisted of different items to the pre-test but testing the same knowledge of the subject matter of the tour. Mobile devices in the form of a tablet (Samsung Galaxy Tab 4) were provided to each group. Of the 60 participants, the experimental condition had a total of 28 individual participants with ages ranging from 7 to 48 years (mean=20.89; sd=14.04). This group consisted of 17 children under 18 years of age (mean=10.35; sd=2.39) and 11 adults (mean=37.18; sd=6.51). The control condition had a total of 32 participants with ages ranging from 8 to 45 years (mean=27.63; sd=13.06). There were 8 children under the age of 18 years (mean=10.75; sd=1.83) and 24 adults (mean=32.88; sd=10.06).
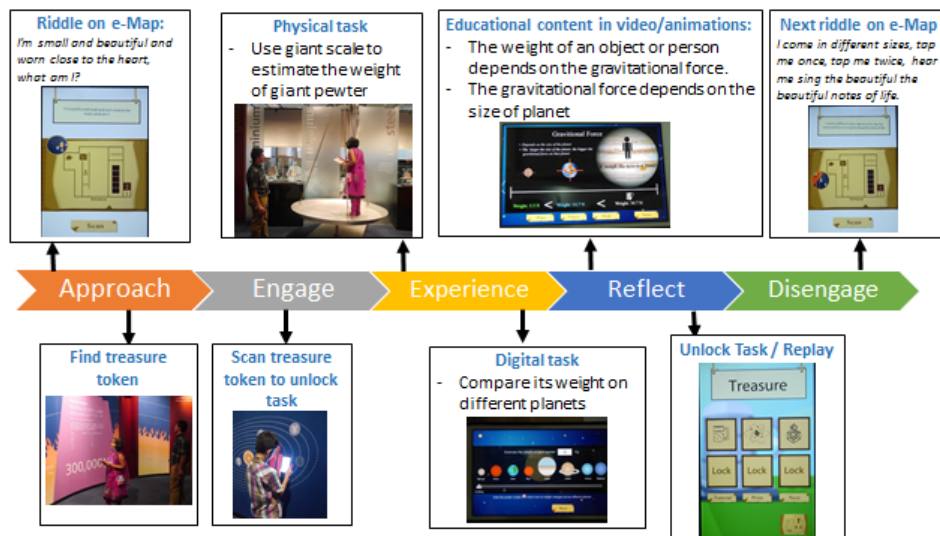
Figure 1. An example of a local trajectory from the exhibit.

Results

Analysis of learning gains focused on the change in performance on tests of knowledge of the science of pewter, before and after the intervention, by age group. A three-way ANOVA was carried out on learning items with test as a repeated measure (pre-/post-) and condition (exp/control) and age group (child/adult) as between subject factors. The intervention using the mobile tour resulted in greater learning gains compared to the control condition. There was a significant main effect of test ($F_{[1,56]}$=5.14, p<.05), with post-test scores being significantly higher (mean=60.48; se=3.32) than pre-test scores (mean=54.49; se=2.32) overall. There was also a significant main effect of age ($F_{[1,56]}$=20.44, p<.01), with adults scoring higher (mean=66.53; se=2.59) than children (mean=48.44; se=3.05). There was no significant main effect of condition, but there was a significant two-way interaction between test and condition ($F_{[2,56]}$=15.21, p<.01). A simple main effects analysis revealed a significant difference between pre- (mean=43.11; se=3.49) and post-test (mean=59.69; se=3.65) for the experimental group ($F_{[1,56]}$=22.44, p<.01), and a significant difference between the experimental (mean=59.69; se=3.65) and control groups (mean=63.17; se=3.42) at pre-test ($F_{[1,56]}$=23.41, p<.01). In other words, although the experimental group happened to perform less well than the control group at pre-test, they succeeded in outperforming the control group in terms of pre- to post-test learning gains.

Video analysis revealed some success in engaging groups to work collaboratively to solve tasks. This may be contributed by the careful design of the tasks requiring participants to look for answers or clues in the physical exhibit environment in order to complete the digital tasks. Our findings also revealed that the role of the adults was an important factor in scaffolding the overall learning experience of the children.

Conclusions and implications

The use of the trajectories framework led us to consider how the learning journey might unfold through key phases of approach, engage, experience, reflect and disengage. Key to our design was the use of visual recognition in an extended user engagement using games in both physical and digital worlds to support collaboration and learning. Result showed significantly higher learning gains for the group with the mobile experience compared with the control group with the usual tour guided experience. This work has contributed further to our understanding of how to segment visitor experience and learning in museums and visitor centres through the use of personal mobile technologies.

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Balancing Expression and Structure in Game Design: Computational Participation Using Studio-Based Pedagogy

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Abstract This paper reports on a project that used a game creation tool to introduce middle-school students ages ten to thirteen to basic elements of computational problem-solving through of studio-based design pedagogy. Instead of adopting a perspective on design education that emphasizes spontaneity and individual creativity, this program employed a programmatic perspective on design practices that emphasizes creativity within set specifications and constraints.

Keywords: design, computational participation, arts, tacit knowledge

Introduction

New scholarship on computational participation places added emphasis on designing and remixing alongside customary conceptions of computational thinking (Kafai, Burke & Resnick, 2014). This paper looks at an afterschool program for youth that aimed to integrate learning about computation within the creative discipline of game design using the Kodu Game Lab game creation software. The project used Kodu to introduce middle-school students ages 10 to 13 about computational problem-solving using studio-based design pedagogy. Instead of adopting a stance on design that emphasized individual originality, this program employed a programmatic perspective that stressed creativity within specified goals and constraints (see Schon, 1983, Hoadley & Cox, 2009).

This curriculum presented students with a structured design challenge over the course of 7 weeks: Participants are challenged to build a racing game level similar to one in Nintendo's well-known Super Mario Kart series. This paper reports on a case study of a learner named Enrique, arguing that his computational practices were shaped by non-linear and tacit "designerly ways of knowing" instead of algorithmic problem solutions.

Theoretical framework: Programmatic pedagogy and design knowledge

The learning environment was crafted with the intent to situate computational participation within the reflective practice of game design. In doing so the research team borrowed from Schon's argument that design disciplines use specialized knowledge to craft solutions to "messy and problematic situations" (1983, pg, 47). In his study of studio architectural students, Schon contended that designing is a "reflective conversation with a situation," not an execution a programmed mental routine. Instead, architectural design entails dialogue with a dynamic *design situation* that has mutually-reliant functional, aesthetic and structural considerations.

Methods and research context

This paper employs multimodal semiotic analysis (Lemke, 2012) to examine the design grammar of a participant's game artifacts, and changes in participants' participation over nine-weeks' time in a case study.

The research took place at a public laboratory school affiliated with a research university. Participants, with their parents' consent, were recruited by affiliated teachers from their classes and from an existing middle-school games club. Between 12-17 participants attended each session, which each ran for one hour.

The first three weekly sessions were focused on teaching participants the minimally-necessary modes of interacting with Kodu, with the aim of providing participants with the foundational skills like game levels creation, programming character movement, programming character's responses to collisions with objects, and programming player characters to interact with non-player characters

Over the next four weeks, the participants were given a design challenge: learn to make a racing game level functionally, mechanically and aesthetically comparable to "Shy Guy's Beach" in *Mario Kart Wii* (see Figure 1).

Findings: Enrique's trajectory

Enrique's evolving designs focused on the primary mechanical elements of the racing game genre – object collection, scoring and finish locations. He experimented early on with game mechanics that at first did not make intuitive sense, but would later on become the foundation of his game design. His initial design was not a traditional looped "racetrack". Instead, his first level featured a "split track", without an opponent, in which the player had to make a choice whether to pursue one path or another (Figure 2).

Coin collection and difficult choices would become key motifs in Enrique's final racetrack design. This design featured an ellipsoid racetrack and two computer-controlled opponents. Coins were scattered across the large racetrack at regular intervals (see Figure 3). Enrique had programmed the player character to acquire points upon colliding with the coins, which would then disappear.

Figure 1. Researcher homage to "Shy Guy's Beach."

Figure 2 - Enrique's split track experiment.

However, if one of the computer-controlled characters hit a coin first, it would deduct points from the player's total (see Figure 4). Enrique forced the player to constantly make difficult choices between racing quickly and acquiring points. The proposed poster will provide further images highlighting the evolution of Enrique's design solutions and supporting programming in Kodu.

Figure 3. Enrique's ellipsoid track with coins.
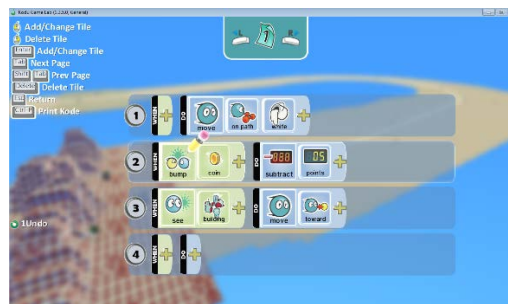
Figure 4. Opponent coin-grabbing reduces score.

Conclusions and implications

First, participants like Enrique were continually reframing the problem space of game design by sketching out ideas in Kodu and testing them in play. Initially, these ideas sometimes did not seem to make sense to adult mentors and other participants. Second, for participants like Enrique the purpose of computational thinking was to serve his expressive capacity in game design. Put differently, the overarching activity of game design became the principal structure for engagement with problems spaces of programming. Enrique confronted programming problems as they emerged in the enterprise of game design.

Design education in art schools like the Bauhaus has taught using the integration of material production techniques (technical knowledge) and mastery of expressive forms (aesthetic knowledge) into a single holistic approach. Given the need to interest young people in computing careers at an early age, perhaps an organized design pedagogical approach that integrated technical competency and expressive capacity would help them see relevance of computing to the vibrant possibilities they see in their world.

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Acknowledgments

Exploring the Development of Scientific Argumentation Practices Among First-Year STEM Undergraduates Through a Writing-to-Learn Approach

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Abstract: This paper describes the features of a *writing-to-learn* (WTL) course for a selected cohort of first-year STEM undergraduate students. We highlight key aspects of their thinking with and development of scientific argumentation through a series of writing assignments, arguing that WTL STEM curriculum strengthens student scientific argumentation skills.

Introduction

Science educators consistently emphasize the importance of scientific argumentation in the development and enculturation of scientific practice. However, for many first-year science, technology, engineering, and mathematics (STEM) undergraduate students, it is difficult to master the series of complex tasks that comprise scientific argumentation. Many reasons exist for this difficulty, namely because of using insufficient data to support claims (Sandoval & Millwood, 2005) and not providing warrants to justify the use of evidence (e.g., Erduran, Simon, & Osborne, 2004). In order to meet the need for STEM students to be successful in future discipline-specific courses and employment, select colleges and universities are beginning to work in cooperation with writing experts to design academic courses which provide opportunities for students to develop their written skills in scientific argumentation. This paper details the experiences of one such *writing-to-learn* (WTL) course for a selected cohort of first-year STEM undergraduate students by exploring and highlighting the key aspects of their thinking with and development of scientific argumentation through their completion of specific writing assignments. Through our findings, we discuss features of this WTL course that allow for the promotion of scientific argumentation development and respond to research that calls for further understanding of what role WTL has in improving scientific argumentation (Reynolds, Thaiss, Katkin, & Thompson, 2012).

Theoretical framework

Various researchers have long supported the view that writing tasks can greatly aid in promoting meaningful learning through metacognition and the structuring and restructuring of mental models (e.g., Holliday, Yore, & Alvermann, 1994; Rivard, 1994). Furthermore, researchers have asserted that these tasks should take diverse forms for different purposes (e.g., Hanrahan, 1999; Hildebrand, 1998). Such tasks are helpful given the complexity associated with scientific argumentation, which involves identifying, generating, critically evaluating, and using evidence to support claims (Osborne, 2010). Given the appropriate writing task, students can carefully choose which content is most effective in clarifying ideas and defending emerging understandings (Hand & Prain, 2002)--skills needed for successful scientific argumentation practices. From this perspective, student writing is viewed as a resource for thinking and learning about scientific argumentation through the use of diverse formats.

Methods

The present study was conducted with a cohort of seven students who are part of a larger longitudinal study, which is examining scientific literacy practices among first-generation STEM undergraduate students at a private university in the western United States. The students were recruited from a required first-year critical thinking and writing course specific for first-generation college students majoring in STEM fields.

Data sources mainly consisted of student artifacts collected over a 10-week period including: (unless otherwise specified, all items were individual student work): 1) critical reading logs (CRL) where students were asked to read an unfamiliar text related to STEM and to identify the author's main argument in a short, informal response (250-500 words); 2) a formal, collaborative analytic summary paper which identified the main argument and argumentative strategies of one reading; 3) a formal, individual critical analysis paper which summarized and made explicit connections between the arguments of two different readings previously explored in a CRL; 4) a formal, individual synthesis paper which identified main arguments of at least three course texts to make an argument about those texts as a dialogic set of arguments; 5) an electronic portfolio which presented key writing

assignments from the course along with reflections that identified useful strategies in accessing and generating arguments of their own.

Using a grounded theory approach (Glaser & Strauss, 1967), we analyzed the student artifacts to identify emergent patterns and themes with the students' development of scientific argumentation skills, namely the ability to articulate an existing claim or argument along with supporting evidence among diverse texts.

Preliminary findings

Preliminary coding of the student artifacts has raised several themes to be investigated further in the longitudinal study. The first theme centers on students' use of personal reactions to identify a claim made by an author. The CRL assignment asks students to identify main claims made in an unfamiliar text and then comment on the construction of the claim, the use of evidence, the purpose of the writing, and the audience addressed. The main objective of this assignment is student recognition of claims in association with presented evidence. Our findings suggest that students initially struggle to identify main claims of these texts in their CRLs; instead students offer broad commentary focused upon their personal reactions to the texts, their associations with the topics addressed in the text, and statements of agreement/disagreement. The second theme emerges from student difficulty recognizing claims in unfamiliar texts; our data suggests that students acquire multiple and diverse strategies for identifying claims and evidence in unfamiliar texts when students progress from individual CRLs to collaborative analytic work. Thirdly, students further develop methods for comprehending and distilling the main claims of unfamiliar texts as they work with several texts simultaneously; student identification of arguments and argumentative strategies becomes less generalized and more inquiry-driven after explicitly studying claim-making.

Conclusions and implications

We argue a WTL approach that incorporates the use of claim identification and making, peer collaboration, and reflection provides an accessible avenue for first-year undergraduate STEM students to develop skills in scientific argumentation. Initial findings suggest that our student participants arrive with limited recognition of claims and arguments made in unfamiliar texts resulting in habits of personalization rather than systematic inquiry. It is plausible that students' improved ability to recognize, articulate, and ultimately compose arguments results from an explicit WTL curriculum for STEM students.

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Exploring Middle School Students' Sense Making of a Computer Simulation About Thermal Conduction

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Abstract: In this study, we explored how students used a computer simulation to construct mechanistic explanations of thermal conduction. We analyzed the interviews of fourteen students and developed a rubric to characterize verbal explanations. We compared the quality of explanations before engaging with the simulation, while engaging with it and again at the end. Results suggests that students with higher prior knowledge tended to mention fewer aspects of the simulation than those with lower prior knowledge.

Keywords: computer simulations, student explanations, heat transfer, conduction, technology, design

Introduction

Simulations have been shown to support student learning as they are flexible, adaptable, have greater accessibility, actively engage students in inquiry-based learning, and they can simplistically represent complex and abstract phenomena (Hilton & Honey, 2011). However, the effectiveness of a simulation depends upon several factors such as the simulation's design features, the role of the teacher in providing support, and the level of students' prior content knowledge (Smetana & Bell, 2012). In this paper, we explore how students made sense of a simulation and how a facilitator helped them construct sophisticated explanatory models about thermal conduction. We define a simulation as a "computer generated, dynamic model of the real world and its processes" (Smetana &Bell, 2012, p. 1338) and a student's explanatory model as an *imagistic mental model* in which the student visualizes the interactions of unobservable elements such as molecules to explain why observable phenomena happen (Ahn, Kalish, Medin, & Gelman, 1995). Our hypothesis is that students who had higher levels of prior knowledge before seeing the simulation will use it to confirm their predictions and those with lower levels of prior knowledge will use simulations as a primary resource to construct their explanation. The ICLS theme of Transforming Learning, Empowering Learners aligns with our work because of our efforts to develop effective learning environments.

Methods

For this study, we interviewed fourteen (9 males and 5 females) middle-school students of different backgrounds from the surrounding area of a large Midwestern University in the United States. We designed a semi-structured interview with three phases. In the first phase, we engaged students in a real world situation about a metal spoon getting hot, we had them draw molecular models, gesture and make predictions. Next, we showed them a simulation depicting a molecular representation of conduction and ended with a request for explanation. The interviews and computer screen were recorded and audio was transcribed. For the analysis, we constructed a canonical explanation of conduction and identified seven necessary explanatory elements. They are (1) The spoon is composed of molecules, (2) Molecules are dynamic, (3) Molecules interact with each other (touch, bump, push, etc.), (4) Hot means faster moving molecules, (5) Cold means slower moving molecules, (6) Fast moving molecules bump into slow moving molecules, and (7) Chain reaction of molecular collisions occurs along the spoon. While reading a transcript, we marked these codes whenever the student explained conduction. For example, we coded 1, 2, and 4 for the following response: 'The spoon's molecules (1) are wiggling (2) and the hot side wiggles more (4)'. A student was judged to have higher levels of prior content knowledge if they mentioned more elements than the first three codes, before interacting with the simulation. To check for reliability, two of the researchers coded two student's transcripts for the presence of these codes. We obtained an inter rater reliability of 87%, discussed and resolved discrepancies before we coded the rest independently.

Findings

Overall, there was an increase in the total number of explanatory elements across the three phases of the interview for 14 students. There were 42 elements mentioned in the pre-simulation phase, 47 mentioned while engaging with the simulation and 58 mentioned in the final explanations. Therefore, students developed more canonical explanations for thermal conduction over the course of the interview. Figure 1 shows a scatter plot comparing the

number of elements each student stated before the simulation and while engaging with it. On examining this plot, there seems to be a negative trend between having higher prior knowledge before the simulation and engaging with it.
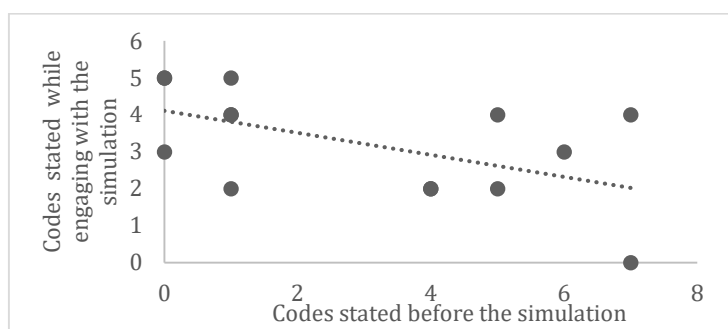
Figure 1. Scatter plot of codes stated before the simulation to the codes states while engaging with it.

A possible reason for this might be that students had qualitatively different discussions with the interviewers depending upon their level of knowledge. To check for this, we examined a student from each case, Naveen (pseudonym) who is point (7, 0) in the above plot and Sanford (pseudonym) who is (0,3) on the plot.

We found that, before watching the simulation, Naveen had already constructed a canonical explanation of thermal conduction. He explained the mechanism by comparing molecular collisions to pool balls. He also drew a molecular model of the spoon that was consistent with canonical representations. However, when viewing the simulation Naveen's interest shifted away from the mechanism to the way the simulation represented equilibrium of temperature. He seemed to be investigating another concept for himself, which he knew was not required for conduction since he did not include this idea in his final explanation. On the other hand, Sanford did not have much prior knowledge about heat or about molecules when he started his interview. When he watched the simulation, he spent more time describing what he saw. After viewing the simulation, Sanford talked about molecules moving and used his hands to describe molecular interactions. He used more elements from the simulation to construct an explanation for heat transfer. The interviewer's encouragement to use his hands helped him further develop his ideas. Therefore, there was a clear difference between the ways Naveen and Sanford used the simulation. While Naveen quickly confirmed his predictions and moved on to investigating other ideas, Sanford spent more time describing, expressing and connecting the elements of the simulation to the case of the spoon.

Conclusions and implications

Results suggest that the simulation was a useful resource for constructing mechanistic explanations of thermal conduction. Moreover, it was helpful because it catered to the diverse needs of the students. Students with higher levels of prior knowledge tended to verbalize fewer explanatory elements depicted in the simulation than those with lower levels of prior knowledge. However, in both situations, the interviewer played a significant role as an instructor and a guide to their explorations. In Naveen's case, the interviewer obliged his explorations in other areas, but for Sanford, the interviewer guided his attention to specific depictions within the simulation and encouraged description through verbal and gestural cues. This shows that appropriate guidance can make a significant difference to student learning. This preliminary work highlights the need for more research on the forms of guidance provided to learners using simulations.

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Acknowledgments

Colors of Nature: Exploring Middle School Girls' Notions of Creativity in an Art/Science Academy

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Abstract: We explore middle school girls' notions of creativity as it relates to art and science in the context of a two-week summer art/science academy. Using Rhodes's (1961) four-dimension framework for analyzing creativity in terms of *process, product, person,* and *press* in order to push on Root-Bernstein's (2003) argument for the overlap in creative processes between science and art, this analysis shows how the girls differentially applied notions of creativity to art and science.

Introduction

Scientists have been found to utilize artistic practices to further their creative scientific work and many see the arts and sciences as complimentary to each other (Root-Bernstein, 2003). In fact, Root-Bernstein (2003) argues that "the ways in which artists and scientists discover and invent problems, experiment with ways to come to grips with them, and generate and test possible solutions is universal" (p. 268). This point comes especially to the fore with the recent release of the *Next Generation Science Standards* (NRC, 2013), which focus on the integration of science and engineering practices with disciplinary core ideas with an aim towards more inclusive science education. Given the transdisciplinary nature of art/science work—sometimes called ArtScience (Root-Bernstein, 2004), this study hypothesizes that arts-based science instruction is a way to deeply connect emerging arts-based identities with STEM-linked identities in middle school girls. We therefore see art-based science instruction as a way to connect youth—in particular youth underrepresented in STEM—with science.

In this study, we seek to understand the notion of creativity and how youth understand it in relation to art and science. Creativity is a notoriously difficult concept to define (Sawyer, 2012). It has been studied from both an individualistic and sociocultural perspective (Guilford, 1950; Sawyer 2007, 2012; Peppler & Solomou, 2011) and has been linked to concepts such as *imagination* and *innovation*. Debates about creativity include questions about *for whom* is an idea/process novel, *which measures* should be used to determine creativity, and *where* creativity is located (Csikszentmihalyi, 1996). In this poster, we draw on a definition of creativity that includes four major dimensions (Rhodes, 1961): Product, or a product that is judged to be creative by some relevant group/groups; Person, or creativity associated with an individual; Process, or processes involved in creative work; and Press, or the context in which creative work takes place. In this poster, we argue that "Press" includes the discursive norms of a domain that structure what is normative in a domain versus what innovative, creative, or outside the norm (Peppler & Solomou, 2011). We use this 4-strand definition of creativity to understand the ways in which middle school girls differentially understand creativity in art and science, how this understanding impacts their identification with art and science, and discuss implications for designing art/science learning experiences that connect notions of creativity across domains.

Methods

The context for this study is a two-week summer academy for middle school girls (N = 60) that ran in the summer of 2015. The academy ran for two sessions for two weeks each, once in a large urban city in the Southwestern United States and once in a small city in the far Northwestern United States. The focus of the academy was "the colors of nature", focusing on the functions of color in biology and art, how color is produced (optical science and art), and how the practices of science overlap with the practices of artists (observation, experimentation, recording procedures, taking notes, publicly presenting scientific/artistic results).

Researchers assumed the role of participant-observers, sometimes interacting with students during activities, conducting interviews with participants, videotaping sessions, and taking field notes. Data sources for this study include pre/post interviews, daily videotaped observations of each day of the academy, pre/post STEM and art attitude surveys and content assessments, and analysis of the girls' science and art notebooks that they kept throughout the academy. This project follows a design-based research (DBR) research paradigm (diSessa & Cobb 2004), with cyclical iterations of design, enactment, analysis, and re-design. Therefore, researchers were involved in all aspects of the design process before the academy as well as daily discussions after each day of the academy to talk about learning and refining the design of learning activities.

Interviews were transcribed and imported into qualitative data analysis software, Dedoose. We coded them for instances of creativity, which included every time the word was uttered but also related terms such as "imagination". We then looked more closely at how the girls talked about creativity and used a constant comparative approach (Glaser & Strauss, 1967; Patton, 1990) to code for four dimensions of creativity: Person, Process, Product, and Press. We examined similarities and differences between how the middle school girls used creativity when referring to art or science.

Findings

Our analysis using Rhodes's (1961) four-dimension framework to analyze the girls' notions of creativity allows us to understand how the girls view art and science differentially, and gives us some insight into their emerging art- and science-linked identities. The girls often described creativity in terms of *process*. They talk about their love of art because it allows them to express themselves and their feelings; it is freeing. Furthermore, they do not seem to think that there are boundaries or "correct" ways of doing art. When the girls mentioned creativity in terms of science, they also discussed how creativity is used to help scientists "think outside the box" and come up with new ways of doing things. The girls also talked about creativity in terms of *products*. For example, one girl described artists as "really creative about like – they can think of a bunch of interesting things to draw that you might not think of as being there. Like they could a draw a butterfly, dragon thing, and you wouldn't have thought of that ever before." Similarly, another girl explained how scientist could use two different tools to come up with a new tool.

While they recognize some similarities between creativity in art and science, they also call out differences. They associate creativity in art with abstractness. In science, they discuss how there are certain constraints in science that do not allow for creativity. For example, one girl talked about differences in drawing in science and art. In science, "…if they're trying to draw something they can't use their creativity because they're science and they have to draw the exact thing otherwise if you're discovering a new species and you sketch it you can't really use creativity." In science, there is a need to accurately represent things or certain procedures to follow that do not allow room for creativity.

Conclusions and implications

While Root-Bernstein (2003) argues that creative processes in art and science are similar, the girls in this study, while seeing some overlap in creativity across the disciplines, make distinctions between what creativity means in terms of process and products. This study suggests that more work needs to be done to determine similarities and differences in creativity in art and science and how they can be developed in complementary and intersecting ways to engage girls in science. Further work must be done to investigate how this then impacts girls' art and science related identities.

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Developing Gesture Recognition Capabilities for Interactive Learning Systems: Personalizing the Learning Experience With Advanced Algorithms

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Abstract: We describe a novel approach to developing a gesture recognition system that accommodates the adaptability and low training requirements of interactive educational simulation environments. Hidden Markov Models allow us to make robust representations of learners' movement in real time, and adapt to their personal style of enacting simulation operations. The context is a project in which gesture-controlled simulations are being built to facilitate the use of crosscutting concepts (e.g., scale and magnitude) across science topics.

Keywords: embodied learning, Hierarchal Hidden Markov Models, learning gestures, motion sensors, quantitative reasoning, scale, simulation

Introduction

Recent research in the learning sciences has focused on the connection between learning and embodied acts such as gesture (Alibali & Nathan, 2012), and there has been increased attention given to the role of embodied design in the creation of effective learning environments (Abrahamson & Lindgren, 2014). Several interactive environments have been developed (Johnson-Glenberg, Birchfield, Tolentino, & Koziupa, 2014) to augment embodied learning, but these systems frequently have had technical limitations such as tracking only the center of mass of a learner or a wand, that can limit the flexibility and expressiveness of the platform.

In this poster we describe our approach to developing a robust gesture recognition system specifically designed to support a range of interactive and immersive learning applications. This system is being developed for a project called Embodied Learning Augmented through Simulation Theaters for Interacting with Cross-Cutting Concepts in Science (ELASTIC[3]S). The objective of ELASTIC[3]S is to develop a versatile platform for implementing STEM learning simulations that can be controlled using body movements that resonate with students' conceptions around crosscutting ideas such as scale and rates of change.

Gesture recognition

The ability to tailor machine-learning models to a specific user's interaction gives designers the powerful ability to connect directly with the individual. Personalized educational tools can directly connect to the needs of specific students and can promote more effective and efficient learning environments if the proper machine-learning model is applied. This need for an adaptable, efficient, real time, yet robust gesture learning model spurs our exploration of Hierarchical Hidden Markov Models as the algorithmic base of our gesture interaction systems. A Hidden Markov Model (HMM) is a dynamic Bayesian network (a probabilistic graph that relates variables over adjacent time steps) that assumes a Markov process (predictions made based only on present state, where future and past are independent). Hidden states control the combination of parameters that are used to generate each observation (Rabiner & Juang, 1986). This allows us to analyze temporal data such as movement in a sequential context, learning transitions between the specific gestures performed by the user.

Scale interview protocols

We began our investigation of what types of gestures support reasoning about cross-cutting concepts by creating a series of interview protocols with middle and high school students. These interviews served two purposes: (1) to collect data about student reasoning on science topics; and (2) to begin developing systems for recognizing learning gestures. We arranged 25 interviews with students who had been recruited from multiple schools in the Midwest area of the United States. These sessions allowed us to ask students to explain their reasoning on a variety of problems in science that involve very small numbers, very large numbers, and non-linear scales, and inquire about how students may express these ideas within an interactive learning system using a variety of gestures.

These sessions began by asking questions that engaged students in thinking about topics that involved non-linear scales, allowing us to elicit reasoning so we could begin to understand their thinking process. Next we asked students to look at a variety of computer simulations that involved scaling such as a bacterial growth, acidity, and earthquakes, all of which use non-linear scales. During this time, we asked a variety of questions such as

"How might you control this simulation to double the present population?" These questions had the students then reconsider our previous line of questioning regarding non-verbal communication, encouraging them to construct an assortment of gestures that might allow them to not only control certain aspects of a simulation, but also interact with various concepts relevant to the topic in which the simulation investigates.

In doing these interviews we were able to find a number of gestures consistent among students. For example, we saw multiple students use a "stacking" gesture to represent doubling; when students described what influenced this, they explained they essentially had two equivalent quantities in each hand, and by stacking what was in the right, on top of what was in the left, they were "doubling" the quantity. As they revisited the questions presented at the beginning of the interview, we saw how the use of gestures grounded their thinking and more accurately supported their reasoning of the mathematical growth.

As our sessions concluded, students would explicitly demonstrate the gestures they constructed throughout the discussion. An application was designed and developed in-house that utilized Microsoft's Kinect v2 motion sensor to capture these gestures during each interview. In an attempt to develop a reliable and expansive database, all gestures were recorded multiple times, and at different scales and speeds. With an array of interview topics and a large selection of students from ranging grades, we were able to investigate the topic of "scaling up" and "scaling down" with respect to non-linear growth. This allowed us to begin developing a small gestural database which will serve to control and interact with the flexible systems and simulations we are designing.

Processing Kinect data to build gesture recognition model

The Kinect captures movement through the generation of depth maps, utilizing a camera and infrared sensor. From these depth maps a skeleton frame representing the spatial position subject can be extracted. The skeletal position can then be transformed into higher-order features such as velocity. The Kinect also provides subjects with a minimally invasive situation where they are not required to wear any additional devices that may inhibit their gestural ability, an essential component for learning spaces where these simulations will be implemented.

To test the potential of 'single instance' learning, we attempted to recognize three separate gesture classes using an HHMM. For training, we used one user-defined example of each class and extracted the x, y, and z velocity of the right hand. On a frame sequence classification task (testing the entire data series up to the current frame), our model recognized each class with the following accuracies:

Gesture 1 = 51/51 (100%)   Gesture 2 = 214/226 (94%)   Gesture 3= 78/113 (69%)

The missed frames of the Gesture 3 class were categorized incorrectly as Gesture 2 (all in succession) at the beginning of the gesture. This can be attributed to the similarities between the classes at the beginning of the gesture. Given the purposefully limited features we used for training, improving accuracy may occur through further experimentation, finding an optimal feature representation. Even in this preliminary task, several of our key hopes were realized. An affordable, non-invasive, lightweight, and flexible system was trained extremely quickly by one user. From these conditions, our model was able to distinguish between three separate gestures in real time. While further testing needs to be done to validate robustness and to recognize variation across class parameters, this case already shows the potential for using these algorithms in our future work. These tests also show the potential for merging the results of learning science research on children's reasoning and gesture with advanced machine learning techniques.

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Collective Regulation of Idea Improvement in Knowledge Building Discourse

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Abstract: This study examined students' collective regulation in knowledge building discourse supported by Knowledge Forum®. Participants were two groups of tertiary students working on Knowledge Forum in principle-based and regular knowledge building classes. Findings show students in principle-based class employed more regulation strategies than regular class. Qualitative analysis of discourse characterized strategies of self-regulation, co-regulation and collective regulation for idea improvement; and regulation strategy was significantly correlated with knowledge advance at both collective and individual levels.

Introduction

This study examined how students collectively regulated their knowledge-building inquiry, mediated by Knowledge Forum®, and to investigate how regulation strategies were related to principles and knowledge advance. Considerable research interests have now been given to self-regulated and co-regulated learning in computer environments; regulation has been theorized as self-regulation, co-regulation as and shared regulation in computer-supported collaborative learning (CSCL) (Järvela & Hadwin, 2013) From a different tradition, knowledge building examines students' collective agency in pursuit of idea improvement and knowledge creation (Scardamalia & Bereiter, 2014). Thus far, current research on regulation in CSCL has focused on task regulation and social regulation but collective regulation pursuing idea improvement and knowledge advancement has not been examined. Issues of interest include how students collectively pursue and monitor inquiry in CSCL not only for task success but for conceptual understanding and pursuit of collective idea improvement. We sought to characterize regulation of idea improvement and we proposed that knowledge-building principles may facilitate and elicit personal and collective regulation strategies that bring about knowledge advances. Research goals include (a) To characterize regulation strategies in knowledge-building discourse and to examine differences in principle-based and regular classes (b) To examine the relations of regulation strategies in forum discourse with knowledge growth both on collective and individual levels.

Methods and Design

Participants
Two classes of first-year tertiary business students in a university in China participated. Both classes employed knowledge building using Knowledge Forum (KF) for two semesters with one using a more intensive model with a principle-based approach (KBP, n=30) and the other regular one (KBR, n=30).

Designs of principle-based Knowledge Building environment
The principle-based KB environment (KBP) employed principles including: (1) epistemic agency with students setting knowledge-building goals and reflecting on difference among ideas; (2) idea improvement and pursuit of inquiry through monitoring the quality of ideas, and (3) community knowledge involving evaluating the state of knowledge and progress. The regular class used KF with less explicit emphasis on principles (KBR).

Data sources
Data included (a) KF participation using server logs including analytic toolkit indices of metacognitive scaffolds (e.g., *I need to understand*; *my theory*) and revision, (b) KF online discourse for analysis of regulation strategies and knowledge advance, and (c) conceptual understanding measured by essays and group report writing.

Results and discussion

Knowledge forum scaffolds, revision and domain understanding
Analyses of KF participation using server logs indicate that KF metacognitive scaffolds and revision were significantly correlated with conceptual understanding (.47, $p<.01$ and .40, $p<.05$ respectively) for principle-based class (KBP) but no relations in regular class (KBR). These findings suggest that students who used more scaffolds and revision to reflect, monitor and regulate their inquiry had better conceptual understanding.

Regulation strategies and relations with knowledge advance and understanding

KF discourse was parsed into inquiry threads and computer notes were analyzed (Zhang et al., 2007). We identified different strategies of regulation adapting from the framework focusing on self, others and groups (Järvela & Hadwin, 2013). Specifically, self-regulation refers to students' reflecting on their own ideas ("*I am quite confused…I now realized*"..); co-regulation involves monitoring others' ideas for improvement ("*In addition to what you have mentioned, you can also consider..*"), and collective regulation refers to students' meta-discourse that synthesizes collective ideas for rise-above inquiry seeking further questions ("*We have discussed a lot; My view on piracy[2] ▧ Partly because…[3] ▧ to organize and integrate[5][Note:red box is reference note from others] Now a conclusion is……but I still need to understand …* "). The different regulation strategies were also rated based on the depth and extent of regulation. Inter-rater reliabilities are currently being conducted.

Regulation strategies and discourse threads (collective knowledge advance)

Students' inquiry threads for KBP (n=23) and KBR (n=13) were coded into three levels representing high-medium- and low-knowledge advances (HKA; MKA and LKA) based on conceptual advance. Table 1 shows higher frequencies of all three kinds of regulation strategies for discourse threads of higher conceptual quality (HKA>MKA>LKA) for both classes. Similarly, ratings show similar patterns: collective regulation is 2.57 and 2.00 in high-level threads; 1.89 and 1.6 in medium-level thread, and both 1.14 in low-level threads for KBP and KBR classes respectively. MANOVA comparing the inquiry threads in KBP and KBR classes showed significant differences on co-regulation, $F = 10.67, p<.005, \eta^2=.24;$ and collective regulation, $F = 4.46, p<.05, \eta^2=.12$. These findings suggest that regulation strategies are related to collective knowledge advance.

Table 1. Means and SD of regulation strategies in high, medium and low threads for both classes.

Knowledge-Building Principles (Thread No = 23)				Knowledge Building Regular (Thread No =13)			
Threads	SR	Co-R	Col-R	Threads	SR	Co-R	Col-R
LKA (7)	3.71(1.38)	4.86(2.27)	.43 (1.13)	LKA (7)	3.86 (.69)	2.29(.76)	.43(.53)
MKA (9)	5.00(2.29)	5.44(2.19)	1.89 (1.36)	MKA (5)	5.60(1.14)	4.0 (1.41)	1.20 (.84)
HKA (7)	10.71(4.5)	13.6(5.19)	4.00 (1.91)	HKA (1)	6.00(.00)	3.00 (.00)	2.00 (.00)

Note: SR=self-regulation; Co-R=co-regulation; Col-R=collective regulation; LKA= low knowledge advances; MKA=moderate knowledge advances; HKA=high knowledge advances; M=mean; SD= standard deviation.

Regulation strategies and domain knowledge (individual)

We also investigated the relations between use of regulation strategies with conceptual understanding at individual level combining the two classes. Correlation analysis indicate that students' understanding was significantly correlated with self-regulation (.40, *p*<.05) and collective regulation (.39, *p*<.05).

Conclusion

This study examined regulation strategies in CSCL in the context of how students collectively regulated their knowledge building inquiry on Knowledge Forum. We characterized patterns of regulation showing how students monitored idea improvement and engaged in meta-discourse in pursuit of collective inquiry; our findings also indicate that the identified regulation strategies were correlated with knowledge advance at both collective and individual levels. Traditionally knowledge building and regulation are separate strands of research; this pioneering study may enrich our understanding of how epistemic collective agency and strategic regulation in CSCL may be combined for productive inquiry and collective knowledge advance. This study also points to the possible role of a principle-based environment with principles providing scaffolds eliciting and sustaining the use of metacognition and regulation strategies. Further investigations are needed to examine the intertwined relations of epistemic principles, collective regulation and knowledge creation in CSCL.

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Impact of Theory Improvement and Collective Responsibility for Knowledge Advancement on the Nature of Student Questions

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Abstract: This study is focused on students' theory development and collective responsibility, and their impact on the nature of student questions. The preliminary results of the study demonstrate that the theory improvement perspective encouraged students to mainly focus on searching explanatory scientific information to construct their own explanations. However, in response to the inquiries, peers main type of contributions was theorizing in which they developed theories in order to deepen their shared understanding and advance knowledge.

Keywords: Knowledge Building, theory improvement, theory-building inquiries

Introduction

In Knowledge Building theory and pedagogy, knowledge is viewed as a social product with students taking responsibility for the state of public knowledge and continual idea improvement (Bereiter, 2002; Scardamalia, 2002; Scardamalia & Bereiter, 2006a). Knowledge Building environments aim to provide opportunities for students to take collective responsibility for the goal of pursuing deeper understanding and explanations of the world—a pursuit which is treated as a form of theory building (Bereiter & Scardamalia, 2012). If that is the case, there should be differences between the nature of questions students ask in regular question-answer inquiries and the questions they ask in theory building inquiries- as well as the way they pursue inquires. In theory building inquiries, students are not simply looking for answers to predetermined questions; rather, they are working together in order to "set up new questions, to generate explanations, and to search for knowledge that might be new both for them and their teachers" (Hakkarainen, 2003). In other words, theory development questions are asked to increasingly deepen students' shared problems and to result in deeper levels of understanding and explanation (Scardamalia & Bereiter, 2006b) that construct new scientific knowledge (Carey & Smith, 1993). In fact, these inquiries help students "form their own questions and work through the process of answering them" (Coffman, 2013, p. 2). This study is focused on the impact of theory improvement and collective responsibility for knowledge advancement on the nature of students' questions, aiming to create a framework for analyses of questions that might distinguish student-driven inquiry (question-answer inquiry) from theory development in which questions lead to a progressive program of theory improvement.

Method and plan of analysis

Dataset

The primary dataset used for this study is Grade 4 students' discourses in science which have been posted in Knowledge Forum®-- a knowledge building environment built specifically to support collaborative production and refinement of the community's knowledge. The data analyzed for this study was a series of student questions-answers, included 89 notes posted by students.

Framework

The study employed ways of contributing scheme (Chuy, Resendes, & Scardamalia, 2010) in which students' discourses in knowledge building science classes are categorized into six different categories and 24 subcategories. As described by Chuy et al. (2010), these categories and subcategories include A) Thought-provoking questions (Explanation, Design, Factual), B) Theorizing (proposing, supporting, improving, seeking alternatives) C) Obtaining Information (asking evidence, testing hypothesis, report experiments, new information from sources, new information from experience, Identifying a design problem, design improvements) D) Working with Information (evidence/reference to support, evidence/reference to contradict, Weighing explanations, Accounting for conflicting), E) Synthesizing and comparing (synthesizing ideas, "risingabove", analogies and comparisons), F) Supporting discussion (Using diagrams, giving opinions, mediating). In order to achieve the purpose of this study, students' questions and peers' responses are analyzed and coded according to the ways of

contributing scheme, aiming to identify types of questions and responses, and the way theory-building perspective affects the nature of questions and the ways students pursue inquiries and answers for continually knowledge advancement.

Preliminary results

The preliminary results of the analyses show that 57.14% of the questions were explanation seeking questions; by which students asked "why something happens" or "how something works". This result indicates that students' inquiry was mainly focused on searching explanatory scientific information in order to construct their own explanations. According to the results, 25% of questions included students' requests for more information, further evidence, or designing experimentations to verify theories or ideas. Finally, 17.86% of questions were factual questions (what, who, and when questions). The analysis of peers' responses to those questions, on the other hand, revealed that the responses were not simple answers to those questions; rather, the majority of responses (40.48%) were theorizing notes in which students proposed explains, provided reasons or justifications to support already existing ideas, or elaborated new details and applied new evidence to improve already existing ideas. The analyses also revealed that 33.33% of responses included new information, relevant analogies to explain ideas, synthesizing and interpreting information from resources, reporting experimental results, or creating "rise above" notes that represent a community knowledge advance. The questions also provided opportunities for students to express their personal ideas (26.19%) in response to the questions. In conclusion, the preliminary results confirm the claims that students' collective vision to build theories, as a goal of Knowledge Building, affects the nature of questions they ask in a knowledge building environment. The results show that the majority of questions were explanation questions; therefore, the study provides an example that engaging students in a Knowledge Building environment encouraged students to ask questions to deepen their understanding of phenomena. On the other hand, the fact that answering explanation questions without elaboration and explanations are not satisfactory (Hakkarainen, 2003) encouraged peers to generate/improve theories and provide evidence to dig down the issues- which is part of idea improvement (Scardamalia & Bereiter, 2006b). The results also show that students' collective efforts to advance knowledge and build theories led them to ask scientific questions; questions that seek further information, evidence, or experimentations to prove ideas. In response, peers provided evidence from authoritative sources, provided new information, or synthesized information.

Future work

For the future work, we aim to replicate the study with more datasets in order to examine whether we would be able to find shifts in the nature of questions and the pursuit of inquiries for the purpose of idea improvement. We also aim to attend in a non-knowledge building class in order to analyze teachers and students discourses (especially posed questions and responses) and examine if there is any difference between kinds of discourses students have in knowledge building and none-knowledge building environments.

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Where the Rubber Meets the Road:
The Impact of the Interface Design on Model Exploration in Science Inquiry

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Abstract: We present a study, in which we examined the impact of the design of a model exploration interface on students' learning process. Students studied how light patterns affected the swimming behavior of some microorganisms. In one condition, students could manipulate both the light patterns and the model parameters and in the other only parameters. The two groups differed in terms of systematicity of their model exploration strategies and learning outcomes.

Keywords: science inquiry, remote laboratories, technology, inquiry strategy, modeling

Introduction

Inquiry-based instruction requires students to model the practices of scientific inquiry to actively develop their conceptual understanding (NGSS, 2013). While physical laboratories were the traditional environments for such inquiry-based learning, there is accumulating evidence that virtual laboratories are similarly well suited to meet the goals of science investigation (deJong, Linn & Zacharia, 2013). However, two major limitations of the research comparing physical and virtual manipulative environments (PME and VME) for science learning were 1. the predominant focus on the learning *outcomes* rather than the learning *processes* when students engage in inquiry activities, and 2. The lack of an understanding of the mechanisms by which affordances of a learning environment, independent of modality, relate to specific learning outcomes. Latter is crucial in particular for people who design the inquiry environments. With this study, we intend to demonstrate a model exploration interface design that allows to manipulate specific parameters of the interface to understand the mechanisms by which design features of interactive systems impact students' inquiry behaviors and learning processes. We present results of a classroom study that examined the impact of interactive affordances of the model exploration interface.

Model exploration interface

We used an interactive hybrid system for exploring microbiology. The phenomenon under study was a microorganism that reacted to light. We implemented a model that is complex enough to capture the essential characteristics of the microorganism while requiring only three parameters (Fig.1): a) *Speed* of the forward movement; b) *Coupling* – the direction and strength of the reaction to light; positive coupling leads to movement towards the light and negative coupling to movement away from the light; the magnitude determines the strength of coupling; 3) *Roll* – the rotational speed about the body axis.

In the model exploration interface, each of the three parameters is controlled by a slider. The parameters can take on only a discrete set of values. The coupling parameter ranges from positive to negative values. The model will never perfectly match the behavior of the real microorganism. Thus, there is no unique solution for the parameter configuration, but a subset of six optimal parameter values that get the model to behave as realistically as possible within the model constraints. When a user starts the simulation after manipulating the parameters (or not), the system creates a visualization of a single three-dimensional model of the microorganism and simulates its behavior in reaction to the light sequence it is exposed to. Each simulation lasts about 30 seconds in total.

Experimental conditions

We developed two interfaces that differed by the interactive affordances and types of visual feedback. In both model interfaces, students could manipulate the three parameters and run as many simulations as they wanted. In the *light (LIGHT)* condition, students could change what direction the light was shining from in real-time, as the simulation was running. However, they could only see the model organism and not the real one. In the *simultaneous (SIM)* condition, students could not change the light but see both model and real organism move at the same time, being exposed to the same, pre-programmed light sequence.

Methods and materials

The study took place in 7th and 8th grade classes of a private K-12 school in the San Francisco Bay Area. It consisted of four 50-minute lab sessions, with a total of 41 students (21 girls, 20 boys). Students worked in pairs (in exceptional cases in groups of three), with one laptop per pair, with an overall of 20 groups.

In both conditions, the goal of the activity was to discover the mechanism of how the organism reacts to light by exploring the coupling and roll parameters. We added a traced path of a real organism in reaction to the pre-programmed light sequence of the real data used in the SIM condition.

The assessment consisted of 5 questions: one asked students to infer a specific light sequence given a Euglena path; three questions asked students specifically about the parameters; one question asked for observed differences between model and real Euglena.

We additionally collected data on all parameter configurations and the light patterns students ran.

Results

Students across both conditions ran multiple experiments, executing the simulation in average 23.1 times (SD=4.3), and manipulating every parameter in at least about 20% of the experiments. All groups either found one of six optimal solutions or came close to them. Thus, student groups in general converged on parameter configurations that enabled them to discover the functionality of all parameters.

The LIGHT condition was marginally better on the light sequence question than the SIM condition, $t(39)=-1.8$, $p=.07$, $d=0.57$, $CI_{.95}=[-0.09,1.23]$; but the SIM condition performed better on the parameter questions, $t(29)=2.21$, $p=.04$, $d=0.77$, $CI_{.95}=[-0.02,1.57]$.

In order to analyze the impact of affordances on experimentation strategies, we characterize students' inquiry strategy by the types of manipulations across all three parameters: 1. Manipulations of only one parameter at a time (CTRL); 2. Manipulations of more than one parameter at a time (MIX); 3. Repetitions of preceding parameter configurations (REP); 4. Short experiments (BURST). Latter is extracted from the time between subsequent simulation runs as defined in the Analysis section. For each student group, we created a four-dimensional strategy vector containing these variables, coded as percentages of total number of simulation runs per group. Based on that data, using Hierarchical Clustering, we found two clusters, a *systematic* and *non-systematic* one in terms of model exploration strategies: The systematic cluster had in average a significantly higher CTRL, $t(18)=5.1$, $p<.001$, $d=2.3$, $CI_{.95}=[0.98,3.59]$, a significantly lower REP, $t(18)=-5.5$, $p<.001$, $d=-2.46$, $CI_{.95}=[-3.80,-1.12]$, and a significantly lower BURST, $t(18)=-3.05$, $p<.01$, $d=-1.4$, $CI_{.95}=[-2.48, -0.25]$. Interestingly, the majority of groups in the SIM condition belong to the systematic cluster (9 / 11), while the majority of groups in the LIGHT condition were in the non-systematic cluster (8 / 9), Fisher's $p<.01$. The clusters differed also in terms of learning outcomes: the systematic cluster was significantly better on the parameter questions, $t(29)=2.4$, $p=.02$, $d=0.85$, $CI_{.95}=[0.06, 1.65]$.

Discussion and conclusions

We found that the SIM condition was significantly better than the LIGHT condition on the questions about the role of parameters and vice versa on the light-related question. In accordance with literature on inquiry strategies in discovery-based activities (Zimmerman, 2000), we showed that the first differences relate to differences in how students went about the task: The cluster analysis of inquiry strategies revealed two groups with consistent patterns of inquiry behaviors; students in the systematic cluster manipulated more often only one parameter at a time, did less repetitions and spent more time between manipulations than the other students. They performed better on the parameter questions and were almost exclusively from the SIM condition. In contrast to previous work, we came to these findings by manipulated design features *within* the same system, hence enabling us to control for other affordances. As a consequence, these results strongly suggest that the differences in strategy use were caused by the differences in the model exploration interface. We will present further discussions at the conference.

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Practitioners' Track

The ICLS 2016 K-12 Practitioners' Track

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Summary

As the Learning Sciences bring together research methods from multiple disciplines to characterize learning in real world settings, the K-12 Practitioners' Track offers educators the opportunity to share their experiences with the Learning Sciences. These experiences include teaching practices from formal learning settings like class lectures, classroom activities, and theoretically informed teacher training sessions. They also include informal learning activities like the design of collaborative spaces for interactive museum exhibits and summer camp experiences. We hope that sharing such experiences will promote discussions between delegates as they consider how educators, professionals, academics and researchers can collaborate with each other to further the contributions of the Learning Sciences in practice.

In Asia, Learning Sciences research places a heavy emphasis on improving learning practices. In addition to answering questions about how to better train competent instructors, curriculum designers, and administrators, it also seeks methods of building research capacity among practitioners so they can feed their findings back into their own teaching and learning designs and diffuse that knowledge throughout their communities.

We are pleased to present a variety of short papers where educators, professionals, academics and researchers, both locally and overseas, have come together to share their experiences in the field. Spanning the topics of knowledge building, technology, and curriculum design, the papers situate their work in formal settings such as schools, and informal settings like a children's museum.

A Comparison of Video Production Styles in Mathematics Flipped Classroom: Examining Students' Preferences

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Abstract: While Flipped Classroom instructional approach has become increasingly popular, there is a lack of research exploring which video production styles are suitable for Secondary School Mathematics Flipped Classroom. We describe our experience of using six different video production styles in a Flipped Classroom learning environment for 24 Form 6 (Grade 12) students. Data sources included student questionnaires and interviews. We found that lecture format with blackboard drawing and PowerPoint lecture with instructor talking head shot video were the two styles that our students liked most. Suggestions were made to guide the production of Mathematics instructional videos for Flipped Classroom.

Introduction

Using instructional videos is an innovative way of teaching and learning, especially when there is a growing interest in using Flipped Classroom (FC). In a typical FC setting, teachers usually prepare instructional videos to guide students' out-of-class learning (Bishop & Verleger, 2013). But, some students are not interested in watching the videos because of the "poor performance in the flipped learning video" (Yang, 2014, p. 160). If students skip the video lectures and come to the class unprepared, the efficiency of their in-class learning will suffer. Guo, Kim, and Rubin (2014) point out that the style of video production can affect student engagement. However, most of the empirical studies on video production styles were related to the higher education context. The findings may not be applicable to guide the design of Secondary School Mathematics instructional videos.

This study aims to explore the use of different video production styles in a Hong Kong Secondary School Mathematics FC context. The data sources we used to achieve this aim included student questionnaires and interviews. Specifically, our goals are twofold: (1) to find out which video production style our students most prefer in Mathematics teaching and their rationales for it; and (2) to provide guidelines for producing Mathematics instructional videos. This study contributes to the knowledge base on the use of video production styles in Mathematics FC contexts.

Design principles underpinning our video lectures

A video lecture usually consists of verbal (e.g., voice) and non-verbal (image) information. In his theory of multimedia learning, Mayer (2014) described how the learner builds representations of verbal and visual information in working memory. To reduce unnecessary memory load, Mayer (2014) proposed three instructional goals: (1) reducing extraneous processing; (2) managing essential processing; and (3) fostering generative processing, along with their corresponding principles (Table 1).

Table 1: Instructional goals and its corresponding design principles for multimedia instruction

Instructional goal	Design principles
Reduce extraneous processing	Coherence: Delete extraneous material Signaling: Highlight essential material Redundancy: Don't add onscreen captions to narrated graphics Spatial contiguity: Place printed words near corresponding part of graphic Temporal contiguity: Present spoken words at same time as corresponding graphics
Manage essential processing	Segmenting: Break lesson into learner-paced parts Pre-training: Present characteristics of key concepts before lesson Modality: Use spoken words rather than printed words
Foster generative processing	Personalization: Put words in conversational style rather than formal style Voice: Put words in human voice rather than machine voice Embodiment: Have onscreen agent use human-like gestures and movements Image: Do not necessarily put static image of agent on the screen
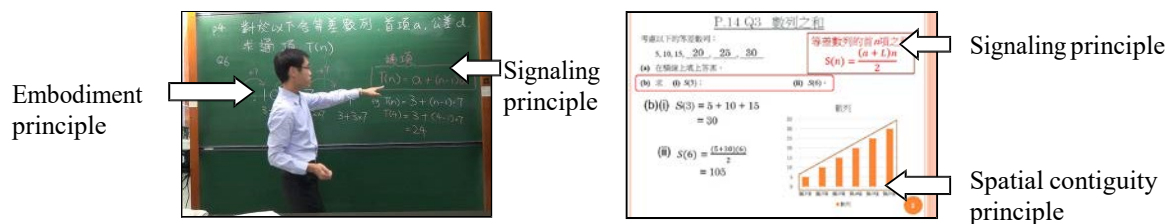
<u>Figure 1</u>. Lecture format with blackboard drawing (left) and PowerPoint lecture with instructor audio (right).

Mayer's (2014) principles served as a foundation of the design of our instructional videos in this study. Figure 1 shows an example of how we used these design principles such as Embodiment principle, Signaling principle, and Spatial contiguity principle in video production. As for Personalization principle and Voice principle, we delivered instructions in a conversational style. Echoing with Segmenting principle, Guo et al. (2014) recommend that the duration of each instructional video should be short and less than six minutes, since this is the median engagement time of learners. In the empirical studies of Secondary School Mathematics FC, teachers usually provide both an explanation of concepts and few simple examples in their instructional videos to facilitate student learning (e.g., Strayer, 2012; Spilka & Manenova, 2014). Therefore we suggest presenting one learning item with two worked examples in our six-minute instructional videos.

Video production styles

Regarding the video production styles, diverse perspectives were found in the literature. While Guo et al. (2014) advocate the use of tablet drawing videos, Chorianopoulos and Giannakos (2013) comment that this style "over simulates private tutoring" (p. 164). When considering teachers' effort on video production, Ronchetti (2010) prefers capturing instructor's teaching in a real classroom since it requires minimal effort. However, Guo et al. (2014) point out that pre-recorded classroom lectures are not engaging even though the quality of video is high. The style of "Slide and animations" is simple to capture (Chorianopoulos & Giannakos, 2013). Guo et al. (2014) further suggest displaying teacher's talking head on slides since it can induce a feeling of "intimate and personal" (p. 45). But in Mathematics teaching, even a sequence of well-prepared slides may not be as effective as blackboard drawing, because writing out on the blackboard "makes visible the process of mathematical reasoning" (Greiffenhagen, 2014, p. 521). Regarding the diverse findings in the empirical studies, exploring students' preferences is thus significant to guide the design of Mathematics instructional videos for FC.

In the present study, we intended to use the videos production styles which were relatively simple to produce. Therefore we used blackboard drawing, PowerPoint lecture, and tablet drawing videos. Six video production styles were used, including (1) Lecture format with blackboard drawing, (2) PowerPoint lecture with interview video, (3) PowerPoint lecture with instructor audio, (4) PowerPoint lecture with audio and photo of instructor, (5) PowerPoint lecture with instructor talking head shot video, and (6) Digital tablet drawing with instructor talking head shot video.

Methods

The main objective of this study is to explore students' preferences of video production styles in Mathematics FC. We addressed the following research questions: (1) Which video production styles should be used in Mathematics FC? Why? (2) What are the suggestions for producing Mathematics instructional videos?

Participants were 24 (10 female, 14 male) Form 6 (Grade 12) students from a Secondary School in Hong Kong. The medium of instruction was Chinese. Prior to this study, they had minimal experience on FC. The course topic was "arithmetic and geometric sequences and their summations" which is one of the learning units in Hong Kong Secondary Mathematics education. Six consecutive sessions were designed. Each session consisted of a video lecture and a face-to-face lesson. In each video lecture, there were two to three six-minute instructional videos and several online multiple choice questions. Six different video production styles were used in the six sessions correspondingly. Students were expected to spend 35 to 45 minutes on each video lecture and attend a one-hour face-to-face lesson for collaborative problem solving activities.

Data sources and analysis

We drew data from two major sources. First, a questionnaire survey was administered at the end of the course. Students ranked each video production style based on their preferences. Spaces were also provided for additional comments. Second, interviews were used to gain in-depth understanding on their perception of each video production style. Using the coding scheme of Corbin and Strauss (2008), guidelines of video production for Mathematics FC were proposed.

Results

Figure 2 shows how students ranked each video production style according to their preferences. Most students (45.8%) ranked lecture format with blackboard drawing the top (Rank 1). But at the same time, several students (25%) ranked this style the least (Rank 6). If we considered students' first two choices (Rank 1 and 2), PowerPoint lecture with instructor talking head shot video was another favorable style (58.3%). Followed by these two styles, students (58.3%) preferred digital tablet drawing with instructor talking head shot video when taking into account students' first three choices (Rank 1 to 3). Among the six video production styles, PowerPoint lecture with interview video was clearly disliked by students. A majority of students (70.8%) ranked it the last or second last (Rank 5 and 6).
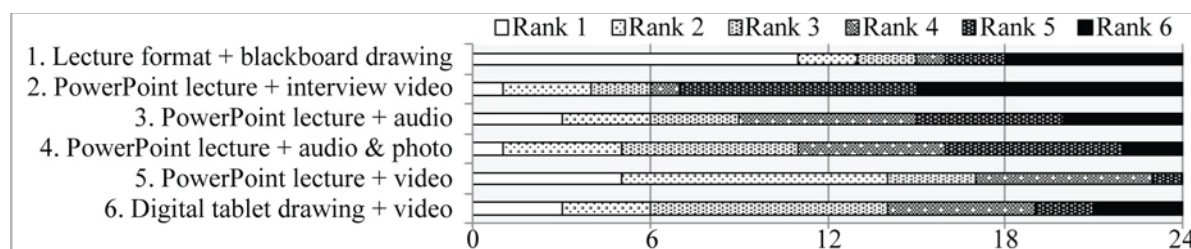
Figure 2. Students' preferences of video production styles by rank (Rank 1 = Highest to Rank 6 = Lowest).

Discussion

In the present study, we identified two most popular video production styles in Mathematics FC, namely lecture format with blackboard drawing and PowerPoint lecture with instructor talking head shot video. As for the digital tablet drawing, although it was considered as the most engaging style in the literature (Guo et al., 2014), it was only moderate popular in the present study.

Lecture format with blackboard drawing

Students preferred lecture format with blackboard drawing because it was similar to a real classroom, which helped students adapt to the new learning approach: "It is easy for me to get used to this format, because it is similar to our normal lessons" (Student 1). Moreover, as highlighted by the following student, "In front of the blackboard, you would point to the words that you were explaining. It was clearer to me" (Student 2). This confirmed the importance of Mayer's (2014) Signaling principle and Embodiment principle.

Concerning the teaching and learning, a student used the term "systematic" to describe teaching Mathematics at the blackboard: "Using blackboard to teach Mathematics seems more systematic" (Student 3). She further elaborated that she could clearly understand how the Mathematics was developed step-by-step. This echoed with Greiffenhagen's (2014) argument that presenting Mathematics at the blackboard showed the materiality of Mathematics construct.

However, several students ranked this style the least. They reported that the texts at the blackboard could not be clearly seen. In fact, they usually accessed the internet and watched online videos by their mobile. As a result, they had to stay at home and watch the instructional videos on PC, which constrained their way of learning. A lack of autonomy thus affected student engagement in the video lecture (Fredricks, Blumenfeld, & Paris, 2004). Some students suggested improving the quality of the video. For example, teachers should "Pay attention to the lighting and avoid having a surface that reflects light" (Student 4) and ensure the texts and figures are displayed clearly through the screen of mobile devices.

PowerPoint lecture with instructor talking head shot video

Among our four PowerPoint lecture styles, students preferred the instructor talking head shot video to the others, which echoed with Guo et al.'s (2014) recommendation of inserting teacher's talking head into the instruction videos. Practically, no student complained about the visibility of texts and figures in this style. Digital graphics seemed best visible to student in various devices such as PC and mobiles.

Students liked the way that the PowerPoint presentation organized. In particular, they pointed out that the "formula box" showed in the slides was very useful (Figure 1), since "It could serve as a reminder for important concepts" (Student 5). According to Mayer's (2014) Signal principle, the "formula box" could highlight the essential material for students. Suggested by Personalization principle, instructors should put words in conversational style. But our results suggested that actual conversation was not necessary in Mathematics instructional videos. Students found it unusual to engage Mathematics learning through interview style and commented that "Direct presentation is fine. No need to use dialogs to teach" (Student 6).

Digital tablet drawing with instructor talking head shot video

Digital tablet drawing with instructor talking head shot video was a moderate popular style in the present study. The result was different from that of Guo et al.'s (2014) findings. But in fact, our research context was not similar to their study. Guo et al. (2014) analyzed the instructional videos from the West, whereas the medium of instruction was Chinese in the present study. Students complained that writing the Chinese characters was "slower than the other videos" and "not clearly displayed on screen" (Student 7).

To summarize (Table 2), we suggest using engaging video production styles and Mayer's (2014) design principles for multimedia instruction. Last but not least, we found that students relied heavily on mobile to access the instructional videos, which allowed them to study anytime and anywhere. For example, "I used my cell phone to watch the video. … In this way, I can watch the video during the time on transport" (Student 8). Teachers should thus ensure the visibility of texts and figures in the video through the screen of mobile devices.

Table 2: Suggested guidelines of video production for Mathematics Flipped Classroom

Guideline	Examples
Use engaging video production styles	Lecture format with blackboard drawing PowerPoint lecture with instructor talking head shot video
Apply Mayer's (2014) design principles for multimedia instruction	Limit the length of each video within six minutes Present one learning item and two worked examples in each video Highlight the important concept by using "formula box"
Ensure the videos can be displayed clearly in mobile devices	Enlarge the texts and figures in videos Pay attention to the quality of videos, especially the recordings are captured in a real classroom setting

Conclusions

In this study, we found that lecture format with blackboard drawing and PowerPoint lecture with instructor talking head shot video were the most popular video production styles in our Mathematics FC. Nevertheless, we cannot over generalize these results and further research involving more student participants is needed. In future research, we suggest applying Mayer's (2014) design principles for multimedia instruction in video production. Also, teachers should ensure their videos created can be displayed clearly in mobile devices. Studies on establishing the design principles of FC instructional video for mobile environment are thus recommended.

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Refashioning Education as a Knowledge Creating Enterprise: Growing Capacity for Knowledge Building in a Grade 1 Math Class

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Abstract: "Knowledge Building" is a pedagogical approach that is focused on engaging students in creative knowledge work and sustained idea improvement. Knowledge Building is a principles-based pedagogy grounded in twelve foundational tenets that serve as drivers of innovation, creativity and knowledge creation. This paper reports how a Grade 1 teacher and support staff started using a Knowledge Building approach in math by testing out small, iterative design experiments aimed to engage select Knowledge Building principles. Through three design iterations, the teachers found ways to increasingly deepen their work related to four targeted principles: "real ideas, authentic problems", "democratizing knowledge", "knowledge building discourse," and "community knowledge, collective responsibility". Emerging from the work, the presence of a fifth, untargeted principle, "pervasive knowledge building", also became evident.

Knowledge building and knowledge creation

Knowledge creating communities are groups whose core work is the production of new knowledge and ideas of value to that community (Chan & Van Aalst, 2014; Scardamalia & Bereiter, 2003). In today's world, progress increasingly relies upon innovative communities and the solutions, and ideas they generate to address all kinds of social challenges (OECD, 2008). Knowledge creating communities take different shapes, but share common traits: they are made up of individuals who work creatively with ideas, nurture a culture of trust and risk-taking, encourage diverse thinking, and feature distributed leadership and expertise (Bielaczyc & Collins, 2005).

So, can a classroom operate as a knowledge creating community? What about a school? From a "Knowledge Building" perspective (Scardamalia & Bereiter, 2003), authentic, creative knowledge work can take place in schools and in classrooms starting from the earliest grade levels. Knowledge Building pedagogy is driven by the commitment to starting students on a developmental trajectory that stretches from the inherent curiousity of children to the "disciplined creativity" characteristic of experts and competent knowledge creators (Scardamalia & Bereiter, 2003). If Knowledge Building had to be described in one phrase it would be "collective responsibility for idea improvement." Knowledge Building is not a set of procedures, but a principles-based pedagogy grounded in 12 tenets that serve as drivers of innovation and knowledge creation (see Table 1). These principles can be thought of as "12 habits of highly creative organizations," as *pedagogical guides*, or *bases for evaluating existing practices*.

Table 1: The 12 Knowledge Building principles

IMPROVABLE IDEAS	Ideas are treated as improvable rather than simply accepted or rejected> *Let's build the best explanation we can.*
EPISTEMIC AGENCY	Learners are empowered to take charge *at the highest levels.*
COMMUNITY KNOWLEDGE, COLLECTIVE RESPONSIBILITY	All participants are legitimate contributors and take responsibility for advancing the community's knowledge, not just their own individual learning.
DEMOCRATIZING KNOWLEDGE	Everyone's ideas are needed and encouraged.
IDEA DIVERSITY	To understand an idea is to understand those ideas that surround it, including contrasting ideas.
KNOWLEDGE BUILDING DISCOURSE	Power is in the discourse--collaborative interchanges that lead to better solutions, better explanations, and better ways forward.
REAL IDEAS, AUTHENTIC PROBLEMS	Efforts to understand the world and improve practice lead to *ideas that matter* to those advancing frontiers of understanding.
RISE-ABOVE	Instead of simply choosing between competing ideas, try to create a new idea that preserves what is valuable in those ideas.

CONSTRUCTIVE USE OF AUTHORITATIVE SOURCES	Find and critically evaluate source material. Build on the authoritative ideas rather than treating them as final.
PERVASIVE KNOWLEDGE BUILDING	Knowledge building is not confined to particular occasions or subjects but pervades mental life.
SYMMETRIC KNOWLEDGE ADVANCE	Expertise is distributed; community members understand that "to give knowledge is to get knowledge."
EMBEDDED, CONCURRENT, AND TRANSFORMATIVE ASSESSMENT	Analytic tools are used to advance knowledge through identifying advances, problems, and gaps as work proceeds.

Methodology: Using design experiments to build capacity for knowledge building

One way to begin to build capacity for Knowledge Building in a way that can align with different problems of practice or school improvement plans is to *select the one or two principles that are most relevant to one's context, and test out very small, iterative design experiments aimed at advancing the frontiers of knowledge.* A question that can help: *Do you see a way to improve or deepen your work in line with any principle?*

A classroom story: Growing a knowledge building community in grade 1

The collaborative team that came together to try out Knowledge Building in Renfrew County included Cindi Chisholm, a grade 1 teacher at Herman Street Public School, Heather Fleming, a Student Success Teacher with the district school board, and Lizanne Lacelle, a District Facilitator for the *Leading Student Achievement: Networks for Learning* "Knowledge Building" project (see www.curriculum.org/LSA/home.shtml), which is supported by the three Ontario Principals' Associations. Together, they created small, manageable experiments designed to engage a few Knowledge Building principles in ways that built off their prior knowledge but also required them to take some risks and try new things. The decided to start by targeting four principles that they found spoke best to what they wanted to achieve. The group's intention was to use Knowledge Building to 1) engage *real ideas and authentic problems* in math; 2) find ways to get everyone engaged, (*democratizing knowledge, community knowledge, collective responsibility);* and 3) encourage the use of new math language (*Knowledge Building discourse).* Key Knowledge Building questions they considered were: *Is this math problem or question authentic from the learners' point of view? How can we get everyone involved? Where can we provide opportunity for peer-to-peer discourse?*

The first element of the initial design experiment was based on the work of Marian Small, and was comprised of presenting the students with a single math question: "Take 20 counters, separate them into 3 piles. One pile has to be double another pile. What are the possibilities?" Partner turn-and-talk was used to provide opportunities for idea sharing and use of Accountable Number Talk. Students were encouraged to explain their thinking and the strategies they used with each other. Student conversations were videotaped and reviewed. Teachers listened for use of math vocabulary, insights, and misconceptions. Upon reflection, the teachers discovered that the original problem was not authentic to the students. The children were confused by the way the problem was phrased and had trouble with the language "doubles" versus "twice as many." This proved a barrier to engagement for some. However, listening to the videotapes of peer-to-peer discourse was key to helping the teachers pinpoint math concepts that students were struggling with (e.g. halving, doubling, splitting) that they could then focus on. They decided to scaffold the activities to build on formal math terms. The teachers also noted questions, ideas and insights that they still want to explore, such as the following:

- When do you intervene to guide students with misconceptions and how much do you tell them?
- Stand back but bring in *timely intervention* by using questions that facilitate students' thinking and encourage them to improve, such as "What is your thinking? What is your strategy?"
- Start a (math) journal to record (number) thinking
- Try the same problem again in the spring to check new thinking

The reflection time was critical to help the group decide how to move forward. They decided that what they needed most was to reflect on how to make the math problem more authentic to the students and also to build on their understanding and productive use of math language. These insights illustrate the ongoing learning occurring during the Knowledge Building process, and set a trajectory for future exploration.

The second design experiment was built around three improved ideas: i) give more opportunities for students to participate in dialogue and use new math terms; ii) make the problem more authentic to students; iii) engage with spatial reasoning by focusing on geometry and visualization of shapes. Teachers also focused more

on the principle of **democratizing knowledge** in this experiment to further empower students as legitimate contributors to shared goals. This was done by providing more opportunities for student-to-student dialogue. In a Knowledge Building community, opportunities for members to engage in peer-to-peer **Knowledge Building discourse** are a priority. Indeed, the importance of mathematical discourse—"math talk" —to achievement and engagement in the subject is well known (NCTM, 2000; National Research Council, 2001). In this grade 1 classroom, collaboration, idea sharing, and Accountable Talk were encouraged by using partner turn and talk, group sharing and a Gallery Walk. A Gallery Walk is a tool used to stimulate group discussion. It calls for students to move around to different areas of the classroom to engage in a particular question or theme assigned to each space. The teachers had used this strategy before, and deemed it to be a useful activity to inspire student-to-student discourse. Geometry, on the other hand, was a new direction to take with the students and a new approach for the teachers for engaging spatial reasoning. Incorporating the use of spatial reasoning through geometry, the teachers' goal was to have students work on spatial visualizaton (imagining various combinations that are possible), composing and decomposing shapes, and understanding equivalence through mental and physical rotations (Ontario Ministry of Education, 2014*)*. Students were given 3D cubes and asked to create as many shapes as possible (see Figure 2). Students sat beside each other on the floor so they could both work independently but be able to see the work of others and discuss with their peers. They were encouraged to show different ways of placing cubes together and describe how they were approaching the task. Students then moved to their desks, and were asked to build as many configurations as possible using four cubes. At a certain point, students became stuck. At this stage, all students went on a Gallery Walk to look at peer structures and talk about how each had built their keys. This was an important kinaesthetic activity to support sustained deep thinking in the face of difficult tasks. Students then went back to their own desks to start building in new ways.
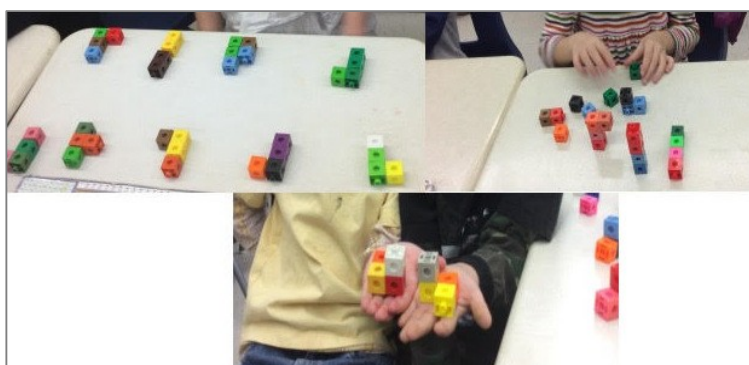
Figure 2. Students build 3D "keys" with cubes

These activities were designed to scaffold the main math problem, which involved students working with 2D tiles. Once the scaffolding activities were completed, the students were presented with the main problem: *"We need to make keys to fit the tooth fairies' treasure boxes. How many keys can you make?"* For this work, students partnered up and were each given a set of keys that were hidden from view. Each partner took turns creating five different key shapes from the 2D tiles, in efforts to try to create one that might be included in the set that they were given. The other partner then duplicated the shape. They then had to find out which key was in the pile and compared the masters to their own. They worked until most of the keys were assembled. Following this, the class discussed all the different configurations of keys. It was during this community sharing that discussions arose about keys being the same, but made in a different direction. As a result of this discovery, math language emerged to express the position of the tiles (turns, flips). Each student was then given a large piece of grid paper and five tiles and asked to construct different keys and to draw them onto the grid paper (see Figure 2). Students were given feedback showing whether keys were duplicated and how many other possible configurations there were. Students were grouped together strategically in teams of four. Each group had students who had created a different amount of keys. Students compared their work, shared ideas, and drew more keys. The shared goal was to have everyone possess all 12 keys for the tooth fairy!

Findings

During this beginning stages of this process, some students were frustrated because the task was "hard." However, the teachers held back from their instinct to "save the kids" and give direct instruction, as one teacher

admitted. They instead invited students to go on a Gallery Walk to build onto one another's ideas. Students persevered. Multiple opportunities for student-to-student discourse helped all students to stay engaged and to succeed. Teachers observed that students were working together, comparing ideas, were engaged and motivated, and were using math language in their discussions with one another. Students were able to imagine, compose and decompose multiple shapes, play with 2D and 3D rotations, and also used new math terms: "flip," "twirl," "turn," "3D," "movement," "upright." Also, evidence of another principle—**Pervasive Knowledge Building**— emerged (one student declared that he "*just couldn't get the problem out of his head!*"). The opportunity to draw the configurations on paper and transfer his visual memory onto a concrete "map" of shapes (see Figure 3) helped him to remember the forms and inspired him to think about the math problem well after class was over.

Figure 3. Students draw key configurations on paper

Discussion and next steps

What will the next design experiment be? Experience with the first two experiments made it clear that in school mathematics it is not easy to find authentic problems—things the students actually wonder about or need to deal with in real life. In natural science there are many kinds of information that can lead children to wonder; the task for the teacher then becomes to help children see the mathematical side of what they wonder about. For instance, reflecting on life spans of different animal species is sure to raise questions about why there are such large differences—from a few weeks to a hundred years or so. Students will come up with ideas, such as that larger animals live longer. That fits the principle of "real ideas." From this, "authentic problems" arise as the students work out how to test their theories—and how to improve them, once they discover that some facts do not fit. The mathematics is in the testing and the reformulating of their ideas. For the teachers, new insights and issues will arise that can lead to Design Experiment #3, and so on in a continuing exploration of ways to bring the Knowledge Building principle of **real ideas, authentic problems** into their mathematics teaching.

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Creating Knowledge Building Communities: Three Case Studies at the Classroom, School and Board Level

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Abstract: How can we refashion education into a knowledge creating enterprise? This work reports three case studies that represent stories of how "Knowledge Building" communities were developed at the classroom, school and district level in three school boards in Ontario. All participants nurtured cultures of trust, risk-taking, and co-learning, and were dedicated to *moving* beyond implementation to *designing and experimenting* with new practices and ideas. Moreover, each participant group was able to align their Knowledge Building work with curricular goals, school improvement plans, and broader system goals. Another essential element for success was having leaders select and engage "champion" teachers as early adopters and influencers. In turn, the support and involvement of the principal was crucial. Finally, participants' own social and pedagogical innovations invited all stakeholders—students, teachers, administrators, and parents—to be meaningfully engaged in the work and allowed for the communities to flourish.

Introduction

Knowledge Building focuses on advancement of community knowledge and sustained, creative work with ideas (Scardamalia & Bereiter, 2006, 2014; van Aalst & Chan, 2007; Zhang & Sun, 2011). In a Knowledge Building community, all members are treated as valid contributors to the collective knowledge pool and all share the responsibility for advancing that knowledge. Knowledge Building shares roots with other inquiry-based approaches, but is unique in that it represents "an attempt to refashion education in a fundamental way, so that it becomes a coherent effort to initiate students into a knowledge creating culture" (Scardamalia & Bereiter, 2006, p. 97). So, how can educators initiate a culture of Knowledge Building in their classrooms and schools? In this paper, we report on three Ontario case studies that detail how Knowledge Building communities were developed at the classroom, school and district levels. We describe shared challenges and highlight key components found to be particularly conducive for creating Knowledge Building cultures in each setting.

Knowledge Building Initiatives in Ontario

In the 2013-2014 school year, two parallel initiatives began in Ontario that centred on introducing and spreading Knowledge Building throughout the province: the "Knowledge Building Initiative," embedded within the Principals' Associations' *Leading Student Achievement: Networks for Learning* (LSA) project, and the "Tri-Board Knowledge Building" project. These projects are supported through a school-university-government partnership that involves the Ontario Principals' Council (OPC), the Catholic Principals' Council | Ontario (CPCO), and l'Association des directions et directions adjointes des écoles franco-ontariennes (ADFO); the Institute for Knowledge Innovation and Technology (IKIT) at the Ontario Institute for Studies in Education (OISE), University of Toronto; and finally, the Ministry of Education, Student Achievement Division, is represented by members of the Literacy and Numeracy Secretariat (LNS) and the Research, Evaluation and Capacity Building branch. The LSA project is guided by the evolving "LSA Theory of Action" framework, designed to help cultivate leadership that positively influences four key conditions that have direct and indirect effects on students (Leithwood, 2012). Work on the Knowledge Building initiative in 2013-2014 led to the development of "A Knowledge Building Theory of Action for LSA" (see Leithwood, Jantzi & Slater, 2014), which illustrates the importance of the Knowledge Building principles and their influence on key learning conditions. Both Knowledge Building initiatives supported by the LSA project share the objective to support teacher professional learning relating to the twelve principles of Knowledge Building (Scardamalia, 2002), and to introduce Knowledge Forum, which is a technology that supports knowledge building processes.

Knowledge Building Communities at the classroom, school and district levels

"Fabulous Fives": Starting Knowledge Building in a grade 5 science class

Jason Frenza was a Gr. 5 teacher at St. Anthony of Padua School in Milton, Ontario, in the 2013 school year. His principal at the time, Karen Dobbie, had selected him to accompany her to an LSA Professional Learning session in November where they were first introduced to Knowledge Building. They walked away very skeptical that it could work for them, but willing to take a risk and try it out. Jason set out to try Knowledge Building for the first time that January. He began with the curriculum. In Ontario, the recently revised Science and Social Studies curricula centre on "Big Ideas" that frame the more specific disciplinary expectations. Jason's first step was to introduce his students to the science curriculum document—a novel experience for both the students and the teacher. Together, they explored the Big Ideas and curriculum expectations, and students were encouraged to pose any questions that they had that they wanted to explore more. Then, they co-created learning goals related to their questions and the Big Ideas. The following describe the practices that Jason found critical for supporting a Knowledge Building culture in his classroom:

- **Knowledge Building Circles**—helped to support differentiated instruction, provided an opportunity to assess expressive language, and helped students understanding the principle of *improvable ideas*.
- **Knowledge Building Reflections**—done after a Knowledge Building Circle and used to provide students an opportunity to reflect upon the Circle discussion. They helped students to develop higher-level questioning.
- **Picture Learning Logs**—allowed students to illustrate science concepts in the form of a picture or diagram. Students make rich connections between scientific ideas and their everyday lives.
- **Mini Conferences**—these repeated sessions allowed the teacher to have rich discussions with students, and record anecdotal assessments. They were one of the most valuable tools for formative assessment.
- **Student self-selected portfolios**—students were asked to identify a variety of artifacts that they produced as part of their work that represented their deepest understandings. Portfolios would be evaluated as a summative assignment using a rubric based on the achievement chart outlined in the curriculum.
- **Knowledge Forum**—was used to extend and deepen face-to-face *knowledge building discourse.* Students made ready use of the scaffolds embedded within the technology to facilitate their dialogue, and also began using the terms in their Knowledge Building Circle discussions ("My theory," "I still wonder about," "New information + source," etc.). Using Knowledge Forum helped increase students' engagement, as they were able to see others interact with their ideas. Knowledge Forum was also used as a mechanism to successfully engage the parent community, as parents were invited to log on and explore the class conversations.

At the onset of the work, Jason was fearful about relinquishing control, whether or not curriculum expectations would be engaged, and how he would assess and evaluate student work. While the first remains his biggest personal challenge, his remaining fears were quickly dispelled. Students who were completely disengaged in the past were now taking charge of their own learning and were enthusiastic and excited about coming to school. As Jason has reported, the students perceived Knowledge Building to be engaging, empowering, and fun.

The story of "Queen A": Growing a whole-school Knowledge Building community

Queen Alexandra is a middle school located in downtown Toronto with a diverse student population. In 2013, a new principal, Emma Nichols, arrived at the school. One of the first things she did was look at a recent survey that had asked students about their experiences and thoughts about the school. Only a fraction of the students reported that they enjoyed coming to school, while the majority felt that there was no caring adult in the building that they could talk to. The principal saw that there was an urgent need to boost student engagement and a sense of community within the school. This need was the main driver of the changes she set out to make.

Success would require getting all the major stakeholders involved, namely, the teachers, the students, and the parents. Beginning with the teachers, Emma discussed with staff their ideas and strategies about what they could do together to improve the situation at the school. The main questions they asked themselves were: *How are we going to increase engagement in school, make learning more relevant and authentic to students, increase student voice, and build community?* They decided that engaging students in an inquiry-based learning approach would be a valuable way to give students more agency and increase motivation. One of the first steps Emma took was to select a couple of talented and influential Grade 8 teachers who could model inquiry practice

as lead learners for the rest of the staff. This helped to begin the process of building a culture of trust and support throughout the school, and set the right conditions in place for the other teachers to try something new and take risks. Additionally, through creative timetabling, space was opened within the teachers' instructional day so that they could come together in Professional Learning Teams (PLTs) to discuss ideas, experiences, and next steps. The great work going on at the school got the attention of Ministry Student Achievement Officers, who then invited the school into the TriBoard Knowledge Building project. Staff and students found that the Knowledge Building principles offered new language for the innovative work that was already going on at the school, and also provided a rich framework to use in order to extend ideas and pursue new directions. For teachers, the twelve principles, along with the Ontario curriculum itself, provided meaningful starting points for classroom work. Teachers worked together to identify "Big Ideas" from across the curriculum that complemented each other and that could provide a robust and cross-curricular frame that could support sustained, creative work with ideas. As Emma identified, a key part of what made Knowledge Building successful was that fact that it was thought of by staff as a principled framework that both helped to catalyze community-building and to convene other board-led initiatives (e.g. STEM learning) in a coherent way.

In terms of engaging the students, the principal and teachers discovered that they needed to focus on rekindling the natural curiosity of their student community. The first step was to explore the Knowledge Building principles to help students start to make the shift from a grades-driven to a knowledge creating culture, and encourage them to become risk takers themselves. Students were given opportunities to engage deeply with authentic problems that had real social significance, and to contribute and develop their own ideas as a community. Once other teachers saw the success of the Grade 8s, they wanted to learn more and be involved. The younger students did as well. In fact, it was the Grade 6 and 7 students who put pressure on their teachers to start Knowledge Building, too. So, within one year and half years, the whole school was involved in the work.

The third major player that had to be involved in order for such a transformation to occur was engaging the parent community. The staff and students had to help the parents understand how Knowledge Building was improving their experiences at school and helping them achieve success. They began a whole educational initiative geared towards helping parents understand what skills and competencies are needed for the 21st century citizen, and how a Knowledge Building approach was helping students develop those capacities. A powerful innovation that staff and students created to help engage parents in the school community was the bi-annual "Inquiry Showcase" in which students presented the culmination of their Knowledge Building work to parents and the broader community. By the spring of 2014 there was a 100% turnout to the Inquiry Showcases. Furthermore, preliminary baseline data in the form of annual student surveys demonstrate an over a 50% increase in students who reported that they "like their school work" and "enjoy coming to school" since the onset of Knowledge Building work in the school (Nichols & Gallagher, 2016). These findings suggest that "bringing to life" Knowledge Building principles such as *community knowledge, collective responsibility* and *epistemic agency* results in greater motivation for knowledge work.

Knowledge Building at the district level in the Upper Grand District School Board

The current team from the Upper Grand District School Board (UGDSB) has been involved with the LSA project since 2010. Knowledge Building became part of the focus of their LSA work in early 2012. Originally, there were 17 participants from three secondary schools and one elementary school. Since then, more than 40 teachers have been trained in Knowledge Building, as well as an additional elementary administrator. Participants represent grades ranging from 6-12, as well as subjects across the curriculum.

The UGDSB group was introduced to Knowledge Building in part through the LSA project, but also through the work of one of their secondary teachers, Glenn Wagner, who had been working with Knowledge Building for his part-time doctoral studies. Along with Glenn, four administrators, Francis Noventa, Chad Warren, Deidre Wilson and Walter Vandervardt formed the core group that began the project at the UGDSB. The intention from the outset was to create a sustainable model for growing Knowledge Building communities across the board. As a first step, it was critical to get the right players on board to maximize the chance for success. The core group appealed to what they called "instructional adventurers" as potential early adopters of Knowledge Building. These were teachers who were resilient, curious, and willing to take risks. The group also appealed to teachers who represented different disciplines, social groups, and technical abilities. Glenn Wagner developed full and half-day workshops to introduce new teachers to the theory and pedagogy. The group also developed a broader PD and Teacher Support Model to sustain the professional learning. Ensuring administrator support and committing to a collaborative, co-learning stance were deemed essential. The ultimate goal was to generate parallel Knowledge Building communities within the classroom, as well as among teachers and district leaders. Their model encompasses six core qualities: i) *Adoption of a KB approach*; ii) *Demonstration of success*; iii) *Participation in the process*; iv) *Opportunity for teachers to plan and explore*; v) *Presence and participation of administrators*;

vi) *Co-learning between administrators and teachers about the process.*

Nurturing a culture of trust and support was a priority, and was supported by giving participants permission to play, make mistakes, and co-developed strategies together that they could experiment with in the classroom. It was also essential that the Knowledge Building initiative be aligned with existing programs and plans in order to not be perceived as an "add-on." Participants were able to make meaningful connections between Knowledge Building and their school improvement plans. For instance, developing 21st century skills such as asking deep questioning skills, thinking critically and learning for deep understanding was linked directly to Knowledge Building practice. Although there had been collaborative efforts between schools and across panels in past projects, the work in developing Knowledge Building Communities was the most collaborative effort to date, with both administrators and teachers working closely together to develop understanding of Knowledge Building concepts and to develop implementation strategy. Since the inception of the project, not a single participant has abandoned the process. Staff members are seeing gains in classrooms and are committed to building their own understanding of the twelve principles. The UGDSB group makes six main recommendations for others wishing to embark on a similar journey in their district: i) *start small;* ii) *appeal to local experts;* iii) *share success stories;* iv) *pick a champion to help spread;* v) *align the work with system initiatives;* vi) *be able to respond to critics.* Next steps include exploring data and evidence in more detail, understanding and addressing limits of expansion, and creating further system alignment.

Conclusion and implications

The three case studies outlined above detail how Ontario students and educators set about creating Knowledge Building communities in their classrooms, schools, and professional learning networks. All participants set out to nurture cultures of trust and risk-taking, and to build communities committed to moving beyond implementation to *designing and experimenting* with new practices and to *advancing collective knowledge*. In each case, utilizing the twelve principles as pedagogical guides, as well as dedicating time for repeated collaborative discussion, helped to keep community idea improvement at the forefront. Participants attribute the success of the work to three main factors: the grassroots, voluntary nature of the projects; rigorous pedagogical principles that can deepen work in classrooms and professional learning; and alignment of Knowledge Building with existing school and board goals. The participants' own social and pedagogical innovations allowed all stakeholders to be meaningfully engaged in the work. Additionally, each story highlights how the support and involvement of an administrator is absolutely essential in each context. Another important element across all cases was professional learning support by experts/consultants. This has included face-to-face presentations at symposia, online presentations in webinars and on site workshops in district hubs and single schools, in particular by Marlene Scardamalia, Carl Bereiter, Monica Resendes and Glen Wagner as well as the LSA District Facilitators. Also, principals and teachers have shared their Knowledge Building journeys extensively with other schools and districts and welcomed visitors to their school and districts to learn with them. This work helps to illustrate how the LSA and TriBoard Knowledge Building projects have provided the structure to connect a distributed network of educators, system leaders, and research representatives to compel and support spread of new ideas and deep learning across the province. Within this distributed structure, the commitment by all participants to engage in knowledge building processes has kept continual idea improvement at the centre.

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Learning Argumentation Using Web 2.0 Tools

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Abstract: Web 2.0 technologies can support students learning argumentation. This paper examines, using a quasi-experimental design, the extent to which the use of Web 2.0 technologies has an impact on the argumentation skills of high school students. At the end of a six- week intervention, the experimental group students improved in their argumentation skills compared to the control group students. The experimental group students with lower English proficiency had higher positive changes in argumentation levels than students with higher English proficiency although survey results showed that students with higher English proficiency felt that they benefited from the intervention. The qualitative analysis of interview transcripts of students indicated that some students felt that Web 2.0 tools helped them develop argumentation skills while others found such tools distracting. The research findings are discussed in terms of pedagogical implications for teachers using technology to teach writing.

Introduction

A perennial concern for English language teachers is achieving better student writing outcomes, especially for students who have lower English proficiency levels. For English language teachers of Grades 11 and 12 students in Singapore, teaching argumentative writing skills is particularly important as the Grade 12 high stakes examinations for local college admission require students to write a 500-800 word argumentative essay on topics such as science, economics, politics, and philosophy.

It is recognized that the objective of having better student writing outcomes might need a different teaching and learning approach. With the advent of technology, new avenues are possible. It is now easier to engage in dialogic pedagogies that allow students to go beyond what they could have achieved on their own (Bower, Hedberg, & Kuswara, 2010). In dialogic pedagogies, students engage actively in discussion, support one another, and together construct meaning in a more social space. Unlike in the traditional classroom where the talk is teacher-dominated or where stronger students dominate classroom talk, all students, especially weaker students, have the opportunity to participate actively in an online space by contributing viewpoints, and by building on what other students write about and asking questions in the discussion. This is an important consideration as students with lower English proficiency tend to be passive in class and are not confident enough to communicate in class (Tan, 2004).

In Singapore, technological tools such as *Voice of Reason* and *Second Life* have been used to help students write better arguments (Ho & Chee, 2011; Jamaludin, Chee, & Ho, 2009). However, there were issues such as access difficulties, time lag, and students' unfamiliarity with the scaffolding tools used (Ho, Rappa, & Chee, 2009). In this study, the Web 2.0 tools used are familiar to both teachers and students and do not face the same technical issues of *Voice of Reason* and *Second Life*. The asynchronous nature of Web 2.0 tools also al-lows students more time to reflect. This aspect is particularly important for weaker students who may take a longer time to reflect before they feel that they are ready to contribute to a discussion, and who do not participate actively in classroom discussion. Not much research has been conducted to find out how weaker students can improve their argumentation skills. However, Kuhn and Udell (2003) did report on a successful intervention that helped foster the argument skills of academically at-risk American adolescents. These adolescents' arguments improved and they used more powerful argumentative discourse strategies such as the use of counterarguments. In a more recent paper, Kuhn and Moore (2015) proposed that that in an argumentation curriculum, students should be first encouraged to address one another's ideas before introducing new ideas as their argumentation becomes more sophisticated. Therefore, it is important for teachers to create a space for students to address one another's ideas. An online space is suitable as it not only allows students to address one another's ideas, they also have more time to reflect and introduce new ideas.

The use of Web 2.0 tools for language learning has become increasingly popular in higher education settings as well as K-12 settings. However, as Hew and Cheung (2013) pointed out in their review of use of Web 2.0 technologies in K-12 and higher education settings, the actual evidence regarding the effectiveness of Web 2.0 technologies is not very strong and very few studies, if any, examined the actual causal effects of Web 2.0 technologies on improvement in student outcomes. This paper examines whether the use of Web 2.0 technologies improved the argumentation skills of students in a high school setting and whether stronger or weaker students benefited from it. It also examines students' experiences with the use of Web 2.0 tools.

Methods

Materials

Both the experimental and control group students were given the same reading and writing materials. The topics covered followed the school's curriculum plan. The teachers were given the choice to use the technology that they were most comfortable with as an online teaching and learning tool. One of the two teachers chose to use *Schoology*, an online learning management tool which has a social media interface to allow students to collaborate with each other. This tool also allows users to create, manage and share content and resources. The other teacher used *Google Docs*, a collaborative website that allows users to upload different kinds of documents.

Participants

The participants were 81 eleventh graders and two teachers in a Singapore high school. To control for teacher effect, each teacher taught one experimental class and one control class. Thirty-two students from two experimental classes responded to the online survey. Students, who scored grades points from 3 to 6 and from 1 to 2 for English language, were assigned to the higher and lower English proficiency groups, respectively. Only 58 out of a total of 81 experimental and control students submitted both the pre- and post-intervention essays (see Table 1 for more details). Consent was sought from all participants.

Table 1: Distribution of participants who submitted both pre- and post-intervention essays

English proficiency	Experimental	Control	Total
Higher	15	12	27
Lower	13	18	31
Total	**28**	**30**	**58**

Procedure

Before the start of the intervention, a master teacher of English language with more than thirty years of teaching experience co-constructed three e-lessons with the two teachers on the topic of youth and family issues. The teachers were taught how to give online feedback to students' comments and questions, and create prompts and questions which would lead to rich discussions. A pre-test essay was administered in the first week of intervention. Experimental group students then participated in both face-to-face and online discussions. That is, the experimental group students were taught argumentation both in the classroom and on *Schoology* or *Google Docs*.

A post-test essay was administered to both experimental and control group students at the end of the six-week intervention. The experimental group students also participated in an online survey and 12 students were interviewed. The results from the pre- and post-test essays from students of the experimental group were compared with similar topic essays from students of the control group. The control group students did not participate in the Web 2.0 technologies-facilitated learning but went through a series of face-to-face classroom lessons on argumentative writing based on the school curriculum. The students were taught how to create arguments by first having a topic sentence and defensible claims. Then, they were taught to substantiate their claim by explaining the reasoning and by providing the evidence to support the claim. They were also taught to identify key terms and requirements of the essay question, and plan their essay by reviewing their stand, alternative points of view and evidence. The general topics taught in class were youth and family, and education.

Data analysis

Erduran, Simon, and Osborne's (2004) analytical framework was used for assessing quality of argumentation, which was based on Toulmin's (1958) Argumentation Pattern. Level 1 argumentation, the most basic level of argumentation, consists of arguments that are a simple claim versus a counter-claim or a claim versus a claim. Level 2 argumentation has arguments consisting of a claim with data, warrants, or backings but with no rebuttals. Level 3 argumentation has arguments with a series of claims or counter-claims with either data, warrants, or backings with occasional weak rebuttal. Level 4 argumentation shows arguments with a claim with a clearly identifiable rebuttal. Such an argument in this level may have several claims and counter-claims. Level 5 argumentation, the highest possible level, displays an extended argument with more than one rebuttal.

To examine the relationship between changes in argumentation level for experimental and control group students as well as for students of higher and lower English proficiency in both groups, the Pearson chi-

square test was performed. Students who improved in their level of argumentation were assigned to the positive change group; those who did not were assigned to the no change/negative change group.

The Spearman rank correlation was performed between the grade point of the experimental group students and their responses towards the survey items. A content analysis was performed on student interviews. The frequency of codes was recorded. Eighteen per cent of the essays were marked by two raters. The percentages of exact and adjacent agreement for the argumentation levels were found to be 62% and 38%, respectively. Thus the percentage of exact or adjacent agreement for the argumentations levels was 100%.

Findings

The results of the Pearson's chi-square test indicated that a disproportionate number of experimental group students improved in argumentation skills compared to control group students and the effect size was large, χ^2 (1, $N = 58$) = 13.52, $p = .0001$; Cramer's $V = .48$. As shown in Table 2, 68% of the experimental group students improved in their argumentation level compared to 20% of control group students.

Table 2: Cross-tabulation of change in argumentation level by group (Observed frequencies)

Change in argumentation level	Experimental	Control	Total
Positive	19 (68%)	6 (20%)	25 (43%)
Negative or no change	9 (32%)	24 (80%)	33 (57%)
Total	**28**	**30**	**58**

Changes observed in students with higher and lower English proficiency

However, the change in argumentation level was only significantly different for students with lower English proficiency in the experimental group compared to those in the control group, χ^2 (1, $N = 31$) = 11.14, $p = .002$; Cramer's $V = .60$. There was a strong association between the experimental students who had lower English proficiency and the development of higher levels of argumentation. The change in argumentation level among experimental group students with higher English proficiency compared to control group students was not significantly different, χ^2 (1, $N = 27$) = 2.97, $p = .09$; Cramer's $V = .33$.

Association between English proficiency and students' perceptions

Results from the Spearman rank correlation test revealed that there was a significant correlation between experimental group students' grade point and their perceptions for the following survey items shown in Table 3. The higher the grade point, the higher was the score for the 5-point Likert scale. Survey items 1 to 3 focused on students' perceptions of how reading their classmates' posts helped their understanding of issues while items 4 to 6 examined how they perceived their online contributions.

Table 3: Correlations between prior English grade point and students' perceptions

	Survey items	Correlation coefficient
1	My peers' posts on various topics have provided me with different perspectives on relevant issues or concepts.	.442*
2	Reading the viewpoints of my peers online helped me to sharpen my own understanding of issues.	.377*
3	Reading my peers' arguments online helped me to arrive at my own conclusions.	.394*
4	My understanding of issues sharpened with my online contributions.	.429*
5	I found it easier to act on my peers' online feedback compared to pen and paper feedback.	.322*
6	Engaging in online discussion forums motivated me to actively assess others' work.	.447*

*Note. *p < .05.*

Findings from student interviews

Students reported that the use of Web 2.0 tools helped improve their argumentation skills (see Table 4). They were able to take a longer time to reflect before writing their arguments. Fellow students gave different perspectives and better feedback on their arguments. They found that it was easier or faster to edit their arguments online. They also found that reading online was more convenient or accessible. However, some students found going online distracting.

Table 4: Students' experiences with Web 2.0 tools

Experience	Code	Frequency	Quote
Positive	Easier or faster to edit online	12	If it's online, then it's like a google document and it is easy to make changes.
	Get better feedback	11	Hmm. I think because it's very good because other classmates can see what I post quickly and they can comment straight away. It's easy for me to get the feedback…
	See different perspectives	10	… you see other people's perspectives, you get a lot of points for your argumentative essays…
	Develop argumentation skills	9	I guess that develops my argumentation skills because you can reply to another reply in the thread.
	More convenient or accessible to read online	6	It's just that online is more accessible compared to hardcopy.
	Have longer time to reflect	4	Maybe on *Schoology*, you, how do you say it, get to process your arguments before you type it down.
Negative	Distracting to use Web 2.0 tool	4	It's sort of, sometimes it's like quite distracting to use because let's say you open an Internet browser, when you use *Schoology*, you get distracted by other things like *Facebook* and *Twitter*.

Conclusion and implications

This study provides some evidence that the use of Web 2.0 tools can help students learn argumentation skills, especially weaker students. This shows that given the affordances of Web 2.0 tools, weaker students who would have been marginalized in traditional classrooms had more opportunities to engage in dialogue on the online platform and thus were able to acquire argumentation skills more easily. This online learning space affords students, especially weaker students, with opportunities to write arguments and to develop their argumentative writing skills. For example, weaker students who tended to be dominated in class by stronger students could contribute arguments address one another's ideas at their own pace.

To help weaker students, teachers can make use of the affordances of Web 2.0 technologies to engage in dialogic pedagogies for the teaching and learning of argumentation skills. As some students might not participate actively in the classroom or need more time to think through their arguments, teachers might be able to address their learning needs better using an online platform as it is asynchronous in nature. Teachers can give their feedback online and track whether students make the suggested changes. Teachers can also use examples from students' online posts in the classroom to highlight how students should or should not write an argument.

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Designing and Implementing the Investigative Skills in Secondary Science Curriculum: A Case Study in Singapore

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Abstract: The present work documents one science teacher's curriculum design work of the investigative skills at one secondary school in Singapore. Drawing upon the Instructional Design Process (IDP), the teacher co-designed with a team of researchers and practitioners a Science Research module that spans over a period of 9 weeks in their second year of middle school. We aim to report how the fundamental design concepts are being applied to such a module, and how the evaluation stage is instrumental to the evolution of the module over time in terms of deliberative inquiry. It is hoped that this model of application of the IDP can be used as a tool for educational transformation and reform for emerging educational program.

The major issues

The School of Science and Technology (SST), Singapore was started as a school specialising in science and technology. It offers an educational experience that is deep in both disciplinary and interdisciplinary learning, immersing secondary students in real-world applications, which require them to transfer their learning and see connections across disciplines. As a school specializes in Science and Technology, there are authentic subjects in the areas of Design, Innovation and Enterprise, and Inter-disciplinary Research Studies besides the traditional subjects of Language, Mathematics, Science, Humanities, and Physical Education. In particular, drawing upon his collaborative design work with a team of researchers and practitioners (Kim, 2015), the first author, as a physics teacher, aims to develop the Investigative Skills in Science (ISS) to make student learning relevant. Since 2011, he has designed and implemented the module of ISS that spans 9 weeks of the Secondary 2 level. Teachers' educational design through partnerships with researchers and practitioners has been described in the literature as essential to the design and sustainability of an innovative technology-enhanced curriculum, yet less is understood about the ways in which teachers initiate the design partnership and educational innovations. Our work differs from previous curriculum studies in that it is a teacher experiencing a critical problem of practice that initiated the design partnership and educational innovations.

Theoretical framework

Influenced by sociocultural studies, the discourse of curriculum has been replaced by the discourse of curriculum making. Curriculum theorists have turned away from academic standards, outcomes and accountability. These changes are crucial for teachers to design an integrated science research program in Singapore. Specifically, the following two aspects of such changes are addressed drawing upon the work of John Dewey and Joseph Schwab who "was the best-known curriculum scholar and amongst the best known of all educationalists" (Connelly, 2013, p. 623).

Psychologizing of the subject matter

Dewey's (1902) analogy between the explorer (the student) and the map (the curriculum) representing the learning journey of the student and the teacher's role as a facilitator shows the importance of synthesizing the logical and psychological ordering of subject matter. For Dewey influenced by Hegelian philosophy, the curriculum is regarded as the map which is "a logical ordering of elements from the psychological experiences of one or more explorers as they wander through unknown terrain" (Phillips, 1998, p. 405). In this sense, students become explorers exploring unknown territory by using available resources (i.e., the map) designed by other explorers including subject experts, curriculum designers, students and teachers. At the result of their exploration, they also contribute to the co-construction of the map that will be available to other learners. Hence, the curriculum needs to be psychologized. In a similar manner, Joseph Schwab (2013) argued that the learner must have an organic connection with the curriculum by proposing the deliberative process of curriculum inquiry employing eclectic inquiry. The deliberative approach is different from the linear, analytical approach in three ways. First, it views the work of curriculum building as one that examines the state of affairs of the learning environment and needs, or in other words, the process seeks to identify curriculum problems, which are often ill-structured and not easily named, and to discuss ways to go about resolving those problems. Second, the deliberative approach capitalizes upon the ideas of many stakeholders and perspectives related to the particular, local, unique situation at hand. Third, the process of deliberation is used to make moral decisions regarding the curriculum. Accordingly, both Dewey and Schwab regard the experience of the learner as the source for the subject matter of a school subject.

They address the importance of a careful analysis of the experience of learners as an essential point for transforming or psychologizing the subject matter in curriculum making.

Practical inquiry

The work of Dewey and Schwab implies that the school subject is as a special form of experience for the learner, and transformative and eclectic deliberation is necessary for a curricular and pedagogical task. In other words, curriculum can be viewed as a practical act, seeking to change the state of affairs. According to Deng (2013), Schwab was saying that the problem with the curriculum field was not that curriculurists were focusing too much on theory or too little on practice, but rather, they were unquestioningly adopting theoretical principles and uncritically applying them to diverse educational settings. Schwab (2013) also saw curriculum work as practical inquiry and moral requiring actions based on critical judgments and decisions.

Methods

Drawing on this theoretical framework, this research required investigation into the actual practices of involving a science teacher's practical inquiry toward developing investigative skills for digital-age learners. To explore this phenomenon, we ask: what are the experiences of the secondary science educator collaborating with university design partners and practitioners to design and implement the ISS module? In this light, the Design-Based Research (DBR) (Collins, Joseph, & Bielaczyc, 2004) approach is effective for the researcher and the research participant (teacher) to become more open, flexible and creative (Kim, 2014) to identify critical elements of the design processes through implementation and modification responding to authentic contexts.

Since 2008, we have established a teacher-researcher partnership at one Secondary school in Singapore to co-design technology-enhanced learning environments (Kim, 2015). Drawing upon our partnership, the teacher initiated designing the Investigative Skills in Science (ISS) module at the SST school in 2011. This study aims to explore teacher learning in the process of designing and implementing the ISS module in the Lower Secondary Science curriculum consisting of 2 physics, 2 biology and 1 chemistry modules. The role of this module is to expose the students to the Science, Technology and Society (STS) curriculum objectives that are relating to the development of scientific skills. The aim is to put the students in the shoes of scientists so that they can experience the collaboration and the inquiry processes. In particular, the time allocated for this module is about one-third of the Secondary Two Science curriculum. With a strong emphasis on this critical process of learning, we hope that students will be able to apply the skills learned in this module to other science subjects that they may take in their third year of secondary school.

The work reported here draws on documentation of Hoe Teck's design work of the ISS module. The ISS module was implemented from 2011 for all the Secondary two cohort of students. There was a population of 200 for the entire cohort taught in 8 classes. We are interested in the teacher's design work in designing and implementing the ISS module as a tool to improve student learning. The teacher (Hoe Teck) documented his teaching practice through his class blog, student artifacts, and his reflective journals. We used these data sources to support our analysis through the process of thematic coding and a constant comparative method (Stake, 2000). By comparing and contrasting the data collected, the following theme emerged pertaining to the experiences of Hoe Teck's design work in designing and implementing the ISS module for his secondary students in Singapore – that is deliberative inquiry.

Significant finding: Deliberative inquiry

There are about 4 teachers deployed to deliver the program each year. Each teacher supervises between 1 to 3 classes of students. The teachers are either Physics or Biology teachers. As the coordinator of the program, Hoe Teck looks into the *deliberative aspects* of the design and implementation of the ISS module rather than a linear, administrative procedure for the ISS development toward predetermined objectives: Formation of teams; Selection of topic; Teaching of the lessons; Supervision and facilitation of the research activities; Providing logistics support; Overseeing of safety in the conduct of the module; Administering of project assessment, peer appraisals and written examinations; Marking of the ISS project using a set of rubrics of assessment; and Setting, vetting and marking of the ISS written examination questions.

Hoe Teck adopted an Instructional Design Process model developed by Foshay (1986) as shown in Figure 1. In order to evaluate the ISS module, drawing upon his collaboration experience with the research team, Hoe Teck initially designed the 19 questions in the survey, relating to the following areas: a) 6 questions on the 6 facets of Applied Learning; b) 10 questions on the 21st century competencies; and c) 3 open-ended questions that relates to the teacher including one good teaching practice that a student feels should be continued, one way in which a teacher can help a student learn better in certain subjects; and one thing that a student appreciates about his/her teacher. Based on the students' detailed performance on each of the rubrics, several areas were identified as under performing. Based on the students' feedback through the survey, Hoe Teck realized that there could be a redesign

of instruction strategy and assessment rubrics. However, when there are issues that could not be solved using the Instructional design, management actions needs to be implemented. Examples of management actions includes: direct feedback to the teacher, job performance aids to the teacher, reward systems for the teacher, teacher selection for the ISS module, and organizational redesign of the ISS module (William & Kazanas, 2004).
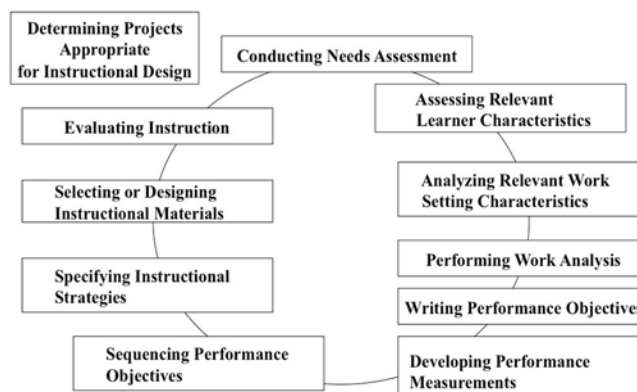
Figure 1. Instructional Design Process Model by Foshay (1986)

After 5 years of implementation from 2011 to 2015, changes were made to the various stages of the instructional design process using feedback from students and their performance in the ISS projects and examination. Table 1 below illustrates the major milestones in the changes made to the ISS module Instructional Design Process. As indicated, these changes were made constantly at different points in the implementation of the ISS module.

Table 1: Changes to the Instructional Design (ID) Process at Various Stages

Stage	Stage of the ID Process	Year	Changes made to the ISS module
1	Conducting needs assessment		Not applicable
2	Assessing relevant learner characteristics		Not applicable
3	Analyzing relevant work setting characteristics	2013	In 2011 & 2012, the ISS module was taught by 2 teachers (1 science and 1 non-science teacher) for each class. This arrangement resulted in some confusion of instructions to the students. From 2013, this arrangement was dropped.
		2013	The ISS module was shifted from term 1 to term 3.
		2015	The ISS module was shifted back to term 1 from term 3 due to clashes in resources (time & Lab space) with the Practical examination for other levels.
4	Performing relevant work analysis (Task and Content Analysis)	2012	Major overhaul was made to differentiate Science Research from General Research that uses surveys as a research tool. The focus was on carrying out experiments in Science Research.
		2012	Task Analysis was increased to include Group Project Presentation in various formats: Written Report, Blog, Video, Poster
		2013	Content Analysis was increased to include Engineering Projects as an option for students.
		2014	Six different types of Science research was introduced to provide a more realistic research approach by different scientists.
		2016	2 new steps in the Scientific Method were introduced, covering areas related to funding and "profitability" of research.
5	Writing performance objectives	2012	Major changes made to the rubrics in 2012. Subsequently, minor changes were made subsequently.
		2013	A different set of assessment rubrics was developed for Engineering Projects.
		2016	The rubrics of assessment were modified to take into account the Survey Findings from the Schools Instructional Program survey.
6	Developing performance	2014	Written examination was introduced and carries a weightage of 10% of Secondary 2 Science Examination results. This increases the ISS weightage from 20% to 30%.
7	Sequencing performance objectives		Not applicable.

8	Specifying instructional strategies	2013	A detailed lesson plan was introduced that specifies the Instructional Strategy to be used: Expository teaching vs. Experiential Learning
9	Selecting or designing instructional materials	2012	Citation Machine was introduced to help students write their references.
		2013	Science Buddies website was introduced to help students identify their research topic based on their interest.
		2014	Reference materials for 6 different Science Research Methods were introduced.

This deliberative curriculum inquiry is different from the traditional analytical approach in important ways. First, it views the work of curriculum making as one that examines the state of affairs of the learning environment and needs, or in other words, the process seeks to identify curriculum problems, which are often ill-structured and not easily named, and to discuss ways to go about resolving those problems. Second, the deliberative approach capitalizes upon the ideas of many stakeholders who could embark on a process of discovery and consensus, seeking integration, being led by an expert in deliberation. Third, the process of deliberation is used to make more decisions regarding the curriculum.

Suggestions for further work and contribution to the Learning Sciences

Although Hoe Teck has attempted to implement the Instructional Design Process diligently to the ISS modules, there are some blind spots that were not identified despite having references to student performance and feedback through the surveys. As most of the changes to the Instructional Design Process were focused on the "Work Setting Characteristics" and beyond, the focus has been on how to implement the ISS module efficiently. This approach does not take into account the important issues, trends and changes that are currently affecting the Instruction at the global scale. In the broader perspective, should there be a change in the Learner Characteristics and Organizational Goals, there should be a significant review of the ISS module to decide whether should it exist in the current form or undergo drastic changes. We have to look into the efficiency and effectiveness so as to achieve the required performance. Practical applications for this Instructional Design are multifold. With the introduction of new courses within the school, we could use the IDP as a template for the design of other courses. Further research can be carried out for other emerging courses, for example, the application of Instructional Design Process on the Makers' Education Movement that requires a myriad of knowledge and skills ranging from innovation, design thinking, digital fabrication, handy craft skills, enterprising skills and to the finished products that are important topics in the Learning Sciences. The content and skills involved would usher in a new paradigm of learning for the 21st century, preparing our students well for the new world trends. We have shared how the fundamental Instructional Design Process concepts are being applied to such a programme, and how the evaluation stage is instrumental to the evolution of the ISS module over time. It is hoped that this model of application of the IDP can be used as a tool for educational transformation and curriculum making that has been often ignored in the field of learning sciences.

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From Passive to Active Learning in A-level Mathematics Classroom

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Abstract: Traditionally, the teaching of A-level Mathematics in a junior college (year 11 and 12) is conducted using the lecture-tutorial system and the learning culture is generally passive. A one-semester long pilot study was conducted using a flipped-classroom approach with an adaptation of Team-Based Learning to teach a group of 62 students in a junior college. The purpose of this change in pedagogy was to promote an active learning culture by creating opportunities for students to take ownership of their learning and be engaged in critical and logical thinking while communicating mathematically. Feedback obtained via survey and interviews showed that this learning approach was well received by the vast majority of the students.

Introduction

At the junior college level (year 11 and 12) in Singapore, lessons are traditionally conducted via a lecture-tutorial system. Students first learn the contents of a new topic during lectures and attempt the questions given in the tutorial exercises after school. During the weekly tutorial sessions, students will clarify any doubts they have with regard to the concepts taught in lectures, and discuss the solutions to the problems that they have attempted. The learning culture during the lectures is generally passive: the lecturer imparts knowledge through content delivering, and the students are expected to take down notes to fill up the set of partially-blank lecture notes. There is little opportunity for students' discussion and experiential learning, as pointed out by Wingfield & Black (2005). Sharing exactly the same sentiments as Michel, Cater III and Varela (2009), students have been observed to have short attention span during lectures. They drift off easily and they either chit-chat with others, or even doze off. Although more than half of the students in a large lecture group of 400 over students may appear to be laboriously copying the notes, feedback gathered from the tutorial sessions showed that there was little or superficial understanding of the contents taught and low retention rate of knowledge learnt.

Such a phenomenon is incongruous to the national education system's desired outcome of self-directed learners who are responsible for their own learning, and they question, reflect and persevere in their pursuit of learning (Ministry of Education, 2009). Likewise, the Mathematics syllabus published by the Singapore Examinations and Assessment Board (2013) for the General Certificate of Education Advanced Level indicates that one of the aims of mathematics education is to develop students' abilities "to reason logically, to communicate mathematically and to learn cooperatively and independently."

In view of the curriculum expectations, there was a pressing need to explore an alternative pedagogy that would promote active learning, engage students in cognitive interaction, and nurture self-directed and independent learners. According to Bonwell and Eison (1991), active learning involves students being engaged in higher-order thinking and "doing things and thinking about what they are doing" (p. 5). Meyers and Jones (1993, p. 6) also pointed out that active learning involves "providing opportunities for students to meaningfully talk and listen, write, read and reflect on the content, ideas, issues, and concerns of an academic subject." Over the decades, educational researchers around the world have called for teachers to move away from a teaching-by-telling approach towards one that promotes active learning of students in the classrooms (Bonwell & Eison, 1991; Meyers & Jones, 1993; Draper, 2002). Team-Based Learning (TBL) (Michaelsen & Sweet, 2008) is a pedagogy that promotes active learning through team-work and peer collaboration. Studies have shown that TBL is effective in promoting mathematical thinking and sense-making through team discussions and arguments that lead to consensus on team answers (Paterson & Sneddon, 2011). Considering its alignment with the desired outcome in Mathematics learning, TBL was adopted in this pilot study to improve teaching and learning. The questions raised are "How will the students respond to the new pedagogy that requires them to take ownership of learning" and "will some students be advantaged or disadvantaged in conducting meaningful mathematical discourse". In this paper, the focus is on the pedagogy used and students' response to the change in classroom learning culture.

Methodology

A purposive sample consisting of three classes with a total of 67 students was selected for this studies. During the period of study, 5 students were transferred to other classes due to a change in subject combinations involving other non-mathematics subjects. These students, with varied mathematics ability across the continuum, were taken out of the lecture-tutorial system to participate in the semester-long pilot study. They

were combined into a mega-class and grouped into ten heterogeneous teams of 6 to 7 per team according to their strength in mathematics, gender and class. Over a total of about 17 weeks of lessons with three sessions of 100-minute lesson per week from Jan to May 2015, students learnt topics that ranged from Pure Mathematics to Statistics.

The lessons adopted a flipped-classroom approach and an adaptation of TBL (Michaelsen & Sweet, 2008). The teaching and learning procedure involved, in sequential order, pre-class reading, individual readiness assurance test (iRAT), group readiness assurance test (gRAT), teacher-facilitated whole-class discussion, application exercises and finally, exit assessment.

Pre-class reading

Students self-learnt the designated contents for each lesson by reading the supplementary PowerPoint slides with explanatory notes and filling up the blanks in the lecture notes. Video-recording of the lectures via Camtasia, a screen-recording software, was also made available online for participating students.

Readiness Assurance Test

This comprised a set of 5 to 10 multiple-choice questions designed to test the basic mastery and simple application of the concepts covered in the designated reading materials. It was conducted at the beginning of a lesson when a new topic or subtopic was introduced. The setting of the questions was carefully planned to ensure its comprehensiveness in covering the learning objectives of the lesson. All distractors used in each question were intentional in surfacing different cognitive misconceptions/errors in learning. The same set of questions was used in both iRAT and gRAT. Both tests were conducted using online software which allowed the teacher to obtain immediate feedback on the performance of each student/group, as well as the overall performance of the class as a whole for each question. The purpose of the test was to monitor the progress of the students in content-learning and to allow the teacher to identify any areas of weakness in learning.

- The duration of iRAT was approximately one minute per question. Using their own smart phones and wireless internet connection, students keyed in their answers.

- The gRAT followed immediately at the end of the iRAT in which the students would retake the test as a team. Each team would discuss the questions with emphasis on the justification of their choice of answers. The online system would provide immediate feedback to each team on the correctness of the answer chosen. When a wrong answer was chosen, the team had to re-deliberate their choice until a correct answer was obtained before moving on to the next question. The duration of gRAT ranged from 15 to 30 minutes, varying according to the number of questions set and the level of difficulty of the questions.

Whole-class discussion

Facilitated by the teacher, students were called upon to provide justifications on their choice of answers. This enabled the teacher to check on those students/teams who have previously made mistakes in iRAT/gRAT to ensure that their doubts were clarified or misconceptions corrected. Students also made use of this platform to further clarify any doubt, express alternative viewpoints or defend their thinking if there were disagreements with the given answers. The teacher could also pose further higher-order thinking questions or address content weakness or any other areas of concern that were surfaced through the readiness assurance tests.

Application exercises

A large proportion of the classroom time was spent on problem-solving with the application of the concepts learnt. The questions set for these were mainly problem sums, which were sufficiently challenging to encourage intra-team discussion. All teams worked on the same problem and would report simultaneously to provide opportunities for rich inter-team discussion. (Team-Based Learning Collaborative, 2013).

Exit assessment

Most lessons would end with an exit assessment to assess students' grasp of concepts learnt and their application. Any learning weakness surfaced would be addressed in the following lesson.

Findings

A total of 56 students, out of 62, responded to an online survey conducted. The purpose of the survey was to find out how the students respond to the new pedagogy and their perception of its efficacy in helping them gain a better understanding of the contents learnt. Three students also volunteered to be interviewed face-to-face.

For the first research question on "how will the students respond to the new pedagogy that requires them to take ownership of learning", 87.5% indicated a preference for TBL lessons as opposed to 12.5% opting for the traditional lecture-tutorial style. Under the flipped-classroom approach, 85.7% (with 46.4% strongly agree and 39.3% agree) expressed that they read their lecture notes much more thoroughly as compared to the traditional mode of lessons. Positive comments from students include:

Student 1: "… overall, I feel more engaged in the lesson and at the same time, (it) ignited my passion in studying hard for the subject."

Student 2: "Not only did we clarify our doubts, but we also reinforced our own understanding by helping one another. When others raised doubts that I had not thought of, it instigates my curiosity which makes me more attentive in the session … it is a very engaging method of learning as opposed to the conventional lecture-tutorial system."

Student 3: "TBL made me learn so much more compared to lecture-tutorial settings. TBL allowed me to learn the chapter by myself and I'm able to remember more things better … Even though there are more things to prepare as compared to the lecture-tutorial setting, I often find myself prioritizing math over other subjects…"

Among the minority who preferred the lecture-tutorial system to TBL, the concern was that they had been doing well in their tests and examinations under the former system, and thus it was unnecessary to spend time on pre-class learning which required personal commitment in both time and effort.

Student 4: "… I feel that it was quite counter-productive …With the lecture system I only need to spend time learning in lecture, go home revise and then attempt tutorials. However, for the TBL system, I have to spend extra time at home viewing the lecture, revising the concept and then doing my tutorials."

For the second research question "will some students be advantaged or disadvantaged in conducting meaningful mathematical discourse", the vast majority indicated that they had benefited from discussions held in the class. Table 1 shows the summarized results of survey questions related to this.

Table 1: Survey results on questions related to students participation in mathematical discourse

Survey questions	Strongly Agree % (size)	Agree % (size)	Disagree % (size)	Strongly Disagree % (size)
Most of the time we discussed the rationale of the choice of each option.	30.4% (17)	57.1% (32)	12.5% (7)	0% (0)
We critically evaluate each other's viewpoints/suggestions.	37.5% (21)	48.2% (27)	14.3% (8)	0% (0)
I managed to clarify my doubts with my teammates.	42.9% (24)	55.4% (31)	1.8% (1)	0% (0)
I had the opportunity to explain the concepts involved to my teammates.	42.9% (24)	55.4% (31)	1.8% (1)	0% (0)
I gained deeper understanding of the concepts involved through group discussions.	46.4% (26)	44.6% (25)	8.9% (5)	0% (0)
The discussion as a class helped to clarify doubts that my group had.	39.3% (22)	57.1% (32)	3.57% (2)	0% (0)

The statistics in Table 1 shows that there is a small percentage of students who indicated that they did not benefit much from the group discussions. Drawing inferences from the free-response comments given by some students, the cohesiveness of a team emerged to be a distinctive factor that determines whether students would be advantaged or disadvantaged in conducting meaningful mathematical discourse.

In a cohesive team, students benefited from the discourse.

Student 5:   "I find my group very helpful in answering each other's doubts and they are also very caring by not allowing anyone to be left behind."

On the other hand, in a less-cohesive team, some students were disadvantaged due to nasty comments made by team members, or unwillingness of some members to share their knowledge.

Student 6:   "… a member in my TBL group has said condescending things to me before which really affected my learning and confidence. Thus I find TBL difficult for me."

Student 7:   "Some of my teammates need to speak up more and share whatever beneficial knowledge that can help us strengthen our foundation for topics."

Conclusions and implications

By and large, the implementation of TBL was successful in changing the learning culture of the class into an active one whereby students took ownership of learning and participated enthusiastically in meaningful mathematical discourse. While this piloted pedagogy was generally well-received by the students, we need to be mindful of the disadvantages and risks involved. There is a need to look into alternative ways of assisting the group of students who could not adapt to this shift of paradigm in learning. This includes strategies on getting students to buy-in, further scaffolding in pre-class learning resources and improving team-bonding. Further research may also investigate, in greater depth, other factors that could possibly affect the quality of mathematical discourse in the classroom, so that with closer monitoring, all students would develop to be motivated, independent and self-directed learners and critical thinkers.

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Acknowledgments

Pop Quizzes – A Journey to Use Formative Assessment to Grow Students and Develop Teachers

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Abstract: In 2015, we embarked on using pop quizzes as a formative assessment tool to raise student achievement and motivation in learning Science. The quizzes were designed to be short and allowed students to document their metacognition, allowing for more accurate feedback by teachers. In addition, frequent professional dialogue was incorporated as part of the process, to encourage discourse on student learning gaps and mentoring by more senior members of the department. After one year, we found that there were significant improvements in student achievement in Science. In addition, we observed several positive changes in the department culture and innovation, after the pop quizzes were implemented.

Introduction

Formative assessment is an essential component in teaching and learning and can raise student achievement (Black & William, 2010). Apart from benefitting students, could we also develop teachers at the same time? In this journey, we sought to explore three questions in the teaching of Science at our school:

1. Can formative assessment be a tool to improve student motivation and achievement, especially for low progress learners?

2. Can we find a balance between using standardized testing to ensure good baseline mastery of the subject versus allowing teachers to differentiate assessment tasks to meet student's needs and ability?

3. Can professional development of teachers be made authentic, frequent and concurrent with day-to-day activities so that it is made meaningful and effective?

Approach and method

We developed a series of pop quizzes, modelled after conventional level-wide, non-weighted topical tests as the main instrument to improve formative assessment for students. To improve student motivation and achievement, especially for low progress learners, we drew on the notion of the zone of proximal development (Vygotsky, 1978), where students were most likely to benefit when assessment tasks are appropriately pitched. By breaking learning tasks into smaller, more achievable steps, we could lower barriers to task completion, allowing lower progress learners to be more motivated and engaged.

Next, we drew on visible thinking routines (Ritchhart & Perkins, 2008) in the pop quiz to elicit student's metacognition. By documenting the student's thinking process, teachers would be able to better to give feedback to students and students would be better aware of their level of mastery.

Also, given our diverse range of learners, we needed to allow for a certain level of differentiated instruction to cater to our learner's needs. By allowing differentiation both in process and product (Tomlinson, 2000), teachers would be able to modify the conduct and expectations of the quiz to match their students' learning readiness.

In summary, we used six principles to guide us in the development of the process. For students, we aimed to (1) lower barriers for task completion; (2) increase frequency and modes of feedback of learning; (3) shorten feedback loop of learning and (4) scaffold metacognition and critical thinking skills. For teachers, we allowed for (5) differentiation in implantation and aimed to (6) make professional development authentic and frequent.

Process design of the pop quiz

Figure 1 below shows the process of how a pop quiz is typically set, discussed, vetted and conducted in class. As

shown in flow chart, the process allows for frequent opportunities for professional dialogue. In addition, vetting of the quiz and post-quiz discussion with the Head of Department / Level Head / Senior Teacher allows for opportunities for mentoring in setting of assessment items.
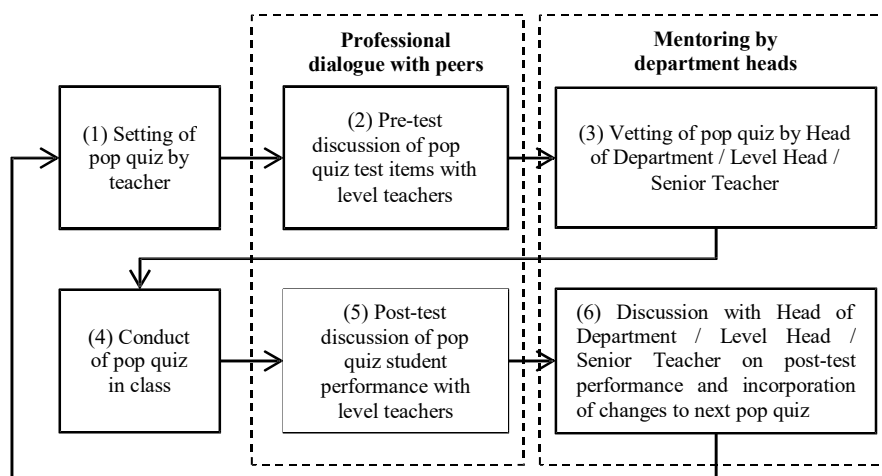
Figure 1. Flowchart of the process design of the pop quiz.

Design of pop quiz

Each pop quiz consists of five multiple-choice questions, with a total test weightage of 10 marks. This is about 10 to 12.5% of the length of a typical Science examination. Students are given 15 minutes to complete the quiz, which gives the student about 1.3 minutes to answer each question, as compared to 2.1 minutes in an examination. Two out of five questions are set to reinforce the current topic taught, and the remaining three questions revisit past concepts. In addition, we included a range of critical thinking skills that were tested across the five questions. Typically, three out of five questions test recall/understanding skills, while the remaining two questions test application, analysis or evaluation skills.

Figure 2. Example of a pop quiz question.

Figure 2 above shows a typical question item for a pop quiz. For each question, students would need to practice and demonstrate the R.H.I.N.O. thinking routine, which guides students in answering multiple-choice questions. R.H.I.N.O. stands for Read the question, Highlight key words, Identify the concept, Narrow your choices and shade on the Optical answer sheet. Students are expected to highlight the key words in the question and write down the concept tested in the question in the space provided. The process of identification of concept is also scaffolded across the levels. As shown in Figure 2, at Primary 3, a multiple choice option is given for students to select the correct concept, at Primary 4 a fill-in the blank question and an open-ended question at Primary 5 and 6. In addition, students indicate their level of confidence of their answer with "VC" being very confident, "NC" being not confident and "IDK" being "I do not know".

Together, the student's answer, markings and highlighted sections on the question and their confidence ratings give the teacher a composite picture of the student's metacognition and understanding of the concept tested.

Conduct of pop quiz in class

The conduct and feedback for a pop quiz is designed to be completed within one period, or 30 minutes. The first 15 minutes will be given for students to attempt the pop quiz. Following that, students will peer-mark their quizzes and the teacher will give feedback on the questions at a class level.

Depending on the ability of the class, teachers have the flexibility to adjust the expectations of the student's answers. For high progress learners, students would be expected to demonstrate their understanding of the R.H.I.N.O. routine, articulate the concept coherently and show confidence in their responses. Conversely, for lower progress learners, teachers would emphasize quiz completion to encourage task persistence and encourage the association of key words and phrases to the question when identifying the concept.

After the class, the teacher will analyze the students' quiz responses. The teacher may choose to give individualized informal feedback in the next lesson based on the responses. For students who demonstrated poor mastery of the concept, the teacher may choose to conduct re-teaching for the concept and retest using the pop quiz to gauge improvement in concept mastery.

Implementation in 2015

In 2015, pop quizzes were implemented school-wide, in all Science classes from Primary 3 to Primary 6. As this was the first year it was implemented, the pop quizzes were conducted every three weeks, to ease teachers into the new programme.

Data collection and analysis

First, we compared the mean year-end assessment grade for the 2015 cohort, versus the mean year-end assessment grade of past three years (2012-2014), using Welch's t-test. This would give an indication of how the series of pop quizzes have impacted student learning of Science.

Next, we compared the mean difference in grades between the mid-year and year-end assessment for each student for the 2015 cohort, versus the mean difference in grades between the mid-year and year-end assessment for each student for the past three years (2012-2014), using Welch's t-test. This would give an indication of how pop quizzes affected student motivation to improve their mastery of Science. As the sample sizes and variances were not equal, Welch's t-test was used instead of Student's t-test.

In addition, to examine the impact on High Progress, Middle Progress and Low Progress learners, we compared the distribution of High Progress Learners (defined as students who scored >80%), Middle Progress Learners (defined as students who scored between 50% and 79%) and Low Progress Learners (defined as students who scored <50%) across the four years.

Results

Impact on student achievement and motivation

As shown in Figures 3 and 4, we found that there were significant improvements in terms of year-end assessment scores as well as improvements made by students within the year.

Average year-end assessment scores

	P3*	P4	P5	P6*
2012-2014	58.6	63.8	57.8	57.4
2015	68.8	65.0	56.1	60.5
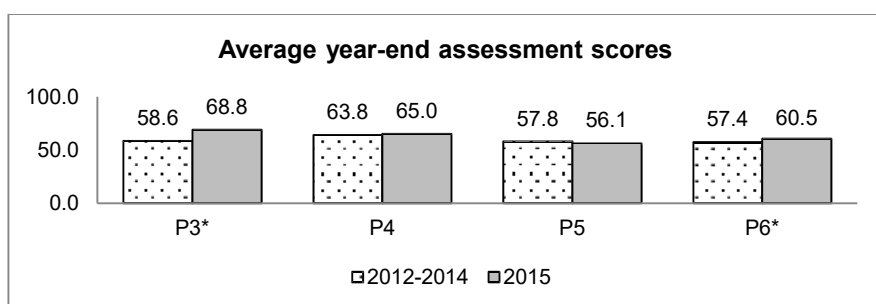
Figure 3. Comparison of average year-end assessment scores for Science for Primary 3 to Primary 6 between 2012-2014 and 2015. The average year-end scores were found to be significantly higher for 2015, as compared to 2012-2014, for Primary 3, t(290) = 5.27, $p < 0.01$, and for Primary 6, t(203) = 1.74, $p = 0.04$.
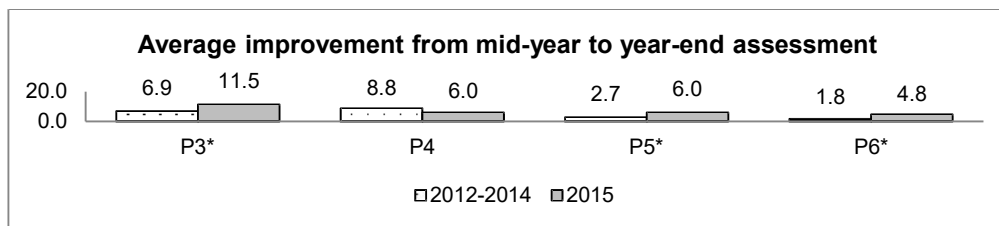
Figure 4. Comparison of average improvement of assessment scores from mid-year to year-end assessment for Science for Primary 3 to Primary 6 between 2012-2014 and 2015. The average improvement in scores were found to be significantly higher for 2015, as compared to 2012-2014, for Primary 3, t(275) = 4.54, $p < 0.01$, Primary 5, t(239) = 4.03, $p < 0.01$ and for Primary 6, t(203) = 1.74, $p < 0.01$.

Impact on different segment of learners

As shown in Table 1, we observed an increase in percentage of high-progress students in 2015 from all levels, as compared to 2012-2014. In addition, we observed a decrease in percentages of low-progress students in 2015 in Primary 3, 4 and 6, as compared to 2012-2014.

Table 1. Comparison of distribution of high-progress, middle-progress and low-progress learners between 2012-2014 and 2015. Numbers in brackets show the change in percentages between 2012-2014 and 2015 for that segment.

Level	Year	% High-Progress	% Middle-Progress	% Low-Progress
Primary 3	2012 – 2014	13.7	47.9	38.4
	2015	27.2 (+13.5)	50.0 (+2.1)	22.8 (-15.6)
Primary 4	2012 – 2014	21.2	50.0	28.8
	2015	23.4 (+2.2)	51.8 (+1.8)	24.8 (-4.0)
Primary 5	2012 – 2014	11.0	49.6	39.4
	2015	13.4 (+2.4)	42.5 (-7.1)	44.0 (+4.6)
Primary 6	2012 – 2014	11.8	51.5	36.7
	2015	15.9 (+4.1)	55.3 (+3.8)	28.8 (-7.9)

Staff feedback and impact on department innovation and culture

Staff feedback on the pop quiz had been positive and many teachers felt that the quiz provided opportunities for re-teaching and intervention. In addition, they observed that lower progress learners were more willing to attempt the quiz and complete it, as compared to longer tests or exercises. Also, regular conversations between department members had made a positive impact on department innovations to better engage and assess student learning.

Implications, conclusion and future studies

Based on the student results and staff feedback, we observed that pop quizzes might have positive impact on student achievement, motivation and staff professional development. Given the positive trends, the department has made pop quizzes a feature in the Science programme for the school.

In the next few years, we would be refining and ordering the questions using Revised Bloom's Taxonomy, so as to test a range of thinking skills. In addition, we will be exploring the use of digital learning platforms to run the tests and use analytics to track and inform student learning at the concept and item level.

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Knowledge Building Pedagogy and Technology: Enacting Principle-Based Design in History Classroom

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Abstract: This study traced the pedagogical moves adopted by a teacher in taking a principle-based approach to designing knowledge building environment (pedagogy and technology) for history lessons. Students, in turns, engaged in mature historical analysis through collaborating and reflecting on their theories on historical inquiry suggesting that Knowledge Building pedagogy and technology are conducive to mature historical thinking. We measured the impact of this approach by the sophistication of students' theories and explanations in terms of the level of historical thinking. Results showed encouraging trends but also pointed towards ways to enhance knowledge construction in history lessons.

Introduction

The essence of knowledge building (KB) classroom focuses on engaging a group of learners in discourse and advance collective knowledge while ensuring that this knowledge is accessible for future use (Lee, Chan, & van Aalst, 2006; Scardamalia & Bereiter, 2003). Such classroom depends largely on teacher's ability to translate a set of Knowledge Building principles to design lessons and organise instruction (Chai & Tan, 2003) in a way that engages students in mature work in the discipline, enculturating them in a learning culture that values their initiation to contribute, add values to ideas, and advance collective knowledge through collaborative discourse (Bereiter, 2002). KB classroom includes integration of Knowledge Forum (KF), an online communal discourse platform that has scaffolds to support students in creating and linking notes (Scardamalia, 2004). In this study, we look at how a history teacher translates knowledge building principles into designing a history classroom to build students' historical thinking.

Knowledge building in a history classroom

Existing literature on knowledge building pedagogy has predominantly focused on science as the subject matter. Bereiter and Scardamalia (2012) explained that generating ideas about scientific phenomena involves exploring scientific laws or principles, whereas generating ideas about social historical phenomena involves exploring theories of a specific case. This difference in the knowledge building practices of the two subjects illustrates that improving knowledge building pedagogical practices for history continues to be an important agenda (Tan, So & Yeo, 2014).

Schema, historical thinking and use of historical concepts

In the learning of history, it is important that students are given the opportunities to make sense of the world as they explore the seemingly distant and dense historical content. They must develop a robust schema, a mental model, to organize and interpret the vast amount of information in a history text. Research on novice versus expert performance (Voss & Wiley, 1998) has indicated that expertise in history requires a mental model that allows for reasoning and problem solving. This schema is an important dimension in developing historical literacy in students. Historical literacy provides a consistent framework upon which to develop historical thinking and students' ability to construct historical concepts. Seixas and Peck (2004) argue that the role of history education is to work with students' fragments of thinking and develop them, so students can learn to think historically and have a better basis for sense-making.

Teachers' principle-design approach to designing the inquiry activities

The teacher has six years of teaching experience and three years of experience with KB practice. In this study, he worked with 39 fourteen-year-old students (19 boys and 20 girls) in an express class (middle-achievers) in a government-aided school. KB pedagogy and technology was adopted throughout the year but this series of lessons were recorded over two week in term three of the school year. He started this series of lesson by designing a set of cognitive scaffold based on the historical concepts defined in the national curriculum document. These cognitive scaffolds took the form of sentence starters to support students in writing notes on Knowledge Forum, a multimedia community knowledge space. The software provides knowledge building supports both in the

creation of notes and in the ways they are linked, it also allows for revisions, elaborations, and reorganizations over time. These scaffolds also serve to support students in navigating the source materials, reflecting their understanding of the information, and crafting explanations of the historical matter. The following segment is a narrative derived from teachers' reflection on his lesson design when the sequence of lessons was completed.

Sparking curiosity (inquiry phase)

Teacher wanted to interest the students in the history topic by engaging students in their own initial questions and ideas about the topic of Japanese occupation. He got the students to post their initial thoughts online and explained to students that the sequence of lessons would be run according to their ideas and inputs in class (Democratizing Knowledge). He also ensured that students embraced the rules of engagement that all ideas are valuable and must be worked upon such that there is diversity of ideas. Example of the different initial questions surfaced by students were, "how was life tough during Japanese occupation?", "Blessings during Japanese occupation?"

Gathering evidence by developing examples of group sources

In a subsequent lesson, the teacher facilitated a classroom discussion around students' theories posted online (students' notes on KF was projected on the wall throughout the discussion). Students suggested that they need to find sources to verify and improve their explanation and theories. They then set off to search and upload relevant sources onto Knowledge Forum, they were encouraged to justify their choice. Students understood that they have to find their way to advance their theories (Epistemic Agency) and they were given opportunities to talk about their contribution in class in subsequent lessons.

Exercising reasoning and reflective thinking

Teacher then built on students' posting that questioned the relevance of the source and got the rest of the students to derive pointers they learnt about relevance before commenting on the rest of the post (Epistemic Agency and Constructive use of sources). In so doing, students were broadening their concepts of 'relevance'. For example, they have learnt that relevance is not about having the source agreeing with the statement. A contradicting source can also be relevant as long as the content relates to the given topic/issue. All through these lessons, the teacher focused on getting students to demonstrate historical thinking surrounding the concept of relevance, the concern of covering historical events and facts was secondary to the development of historical thinking.
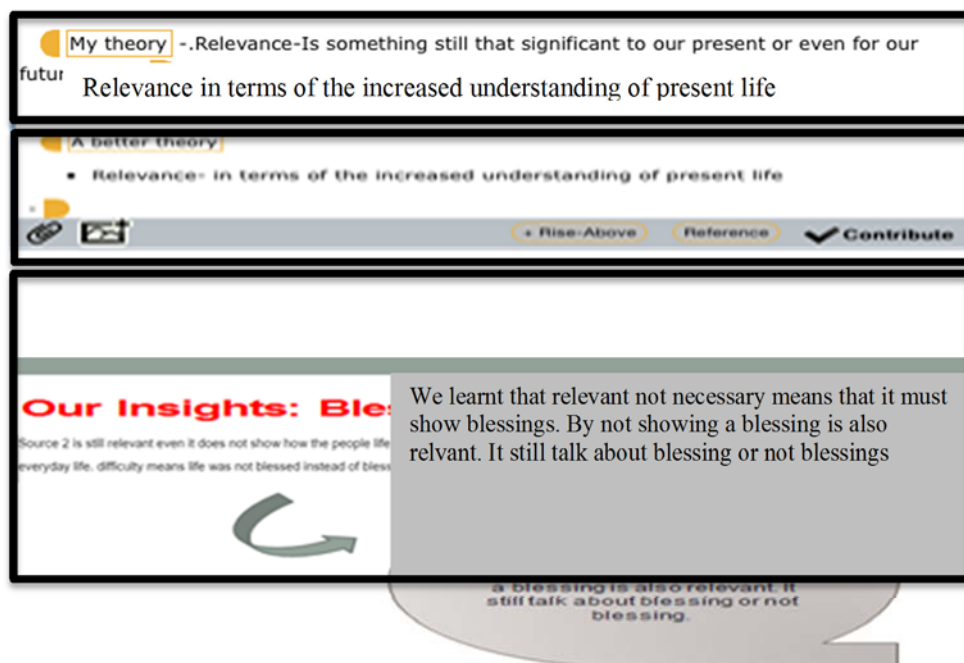
Figure 1. Three sets of students' notes using scaffold "my theory", "I need to understand", and "rise-above".

Rise above

At the final stage of inquiry, the class was tasked in groups to craft explanations that incorporated and synthesized

prior knowledge, new information and new understanding acquired throughout the process to respond to the overarching question, "Was it true that Japanese Occupation in Singapore only brought forth negative impacts to the people?". This question was synthesized from students' questions in first view. Upon studying students' responses, teacher reflected that he saw a shift in students thinking. Students were able to adopt different sets of KB scaffolds to help them progress in the writing of their group response, they showed a more robust view of the topic by challenging some conventional thoughts and they were able constructed more diverse yet coherent explanations. Below is a snippet of students' rise-above note which the teacher analysed as "(in the note) students has constructed a non-monolithic thinking, adopt both perspectives [non-conventional approach in the study of JO which usually focuses on negative]."

> Japanese Occupation helps people to come together as one, regardless of races. This is very different from British time. This is something that is positive to the people in Singapore. But, we also agree that there are also sources showing Japanese Occupation also bring forth negative impacts. (snippet of students' note taken from KF)

Analysis

To find out how the KB environment impacted students' development of historical literacy skills, 586 students' notes collated across three weeks and two different KF views on different aspects of Japanese occupation posted KF were analysed using the coding scheme in Table 1. (KF Views are 'pages' on KF that provide a visual organization for notes. A KF view allows one to see all related notes and it represents related ideas and discussion strands.) The notes that were analysed were mainly written with sentence starters such as "my theory", "a better theory", "pulling our knowledge together", "new information that depicted students' theories, explanation, and rise-above.

The coding scheme is built from existing literature that has identified six distinct but closely related historical concepts as a framework for assessing historical literacies skills. The six concepts are: Historical Significance; Evidence (Use of Historical Sources); Continuity and Change; Cause and Consequence; Historical Perspective; and Moral Judgement. In the present study, a gradation scheme was created to chart developments in students' understanding of these six historical concepts across the three KF views. The gradation scheme is as follows (Table 1):

Table 1: Coding scheme on progression of students' historical literacies skills based on level of sophistication of notes defined by the integration of historical concept

Categories	Descriptions	Examples
Level 1	No awareness of historical concepts	-
Level 2	Superficial understanding of historical concept as a way to "answer" to a question.	*"Source 2 underlined answered the question of how tough days were back then during the Japanese occupation."*
Level 3	Use of historical concept as part of the explanation.	*"My theory -Source 3 is relevant because the source shows that how hard it is to get food for living."*
Level 4	Elaboration of historical concept in explanation (usually involves personal thoughts or theories)	*"My theory -source 1 show(s) us how life under japanese occupation was tough, i agree as it shows us how Elizabeth choy got torture by iapanese occupation and the method of making her husband feel useless. Back then women does not have any protection"*

Findings

It is generally evident from the results that students' historical literacy skills improved significantly over the course of the KB lessons. The overall pattern is that, as the project progressed and lessons continued, students' historical literacy skills were showing increasing level of sophistication. With such positive shift in students' historical literacy, the teacher reflected and surfaced two points to be considered in his next cycle of lesson design, first, he felt that there could be higher level of autonomy given to students throughout the inquiry process and second, he felt that more effort could be used to unpack the rise-above principles to students so as to allow them to assess and own the new knowledge they created throughout the lessons.
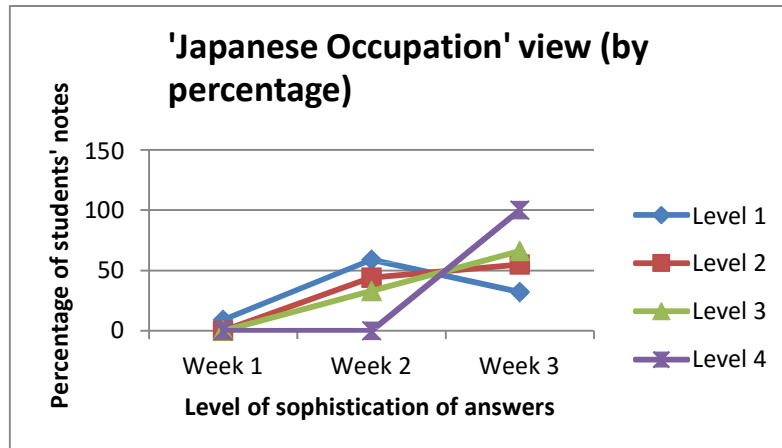
Figure 2. Level of sophistication of students' posting online across three weeks.

Conclusion and implications

In summary, results reflect that a KB environment can benefit students' learning of History, as it increases students' development of interest in the subject, as well as their historical thinking. The key role of history teacher lies in their interaction with students. Such interactions includes a collective effort in posing guiding questions, having rich conversations, providing scaffolds to help students see patterns in history events and text and finally, facilitating students' independence in knowledge construction process.

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Nurturing Positive Learning Outcomes: The Role of the Interlocutor

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Abstract: This study features efforts to develop evaluation standards about the effect of the verbal engagement and skills of interlocutors during a creative outreach program with young children from marginalized backgrounds in Singapore. A principal focus of the investigation is the role of language in creating a context for building social-emotional learning (SEL) competence. Based on transcription of in situ video recordings, this study used Halliday's Systematic Functional Linguistics (SFL) to understand the relationship between the interlocutor and SEL program outcomes. Findings revealed the effectiveness of an SFL approach to measuring the interlocutor's interactions with the participants. Reflexive practices and mentoring brought awareness and improvements in the interlocutor's verbal performance when children were encouraged to explore their ideas. Theoretical understanding of the nature of verbal interactions brought awareness of the methodological application of SFL and may further improve pedagogy, practice and outcomes of creative program content and the development of SEL.

Introduction

This paper is part of a larger study on the design of a creative outreach program for children from low socio-economic backgrounds in Singapore. One of the challenges was to develop evaluative measures to provide accountability and identification of the various factors that influenced the execution of the program. The program was founded in the belief that play and art provide tools that build confidence and lead to better adaptive and social-emotional (SEL) behaviours. SEL refers to five domains of skills to manage self, relate to others positively and make responsible decisions (CASEL, 2008; MOE, 2016). The aim of this part of the study was to understand the effect of the verbal interactions of the interlocutor on children's engagement and SEL development. Briefly, an interlocutor is defined as a participant in dialogue whose language and role is significant in the development of thinking (Haas Dyson, 1995). It was hypothesized that the language use of the interlocutor is pivotal in the development of positive social and emotional learning (SEL). Socio-cultural theorist Halliday (1978, 2009), inspired by Vygotsky (1978), suggest that meaning and language are part of social processes. This part of the investigation explored Halliday's Systematic Functional Linguistics (SFL) to understand the effect of the interlocutor's language use in program execution. Transcriptions of in-situ video observations provided the data. Attention to frequency, direction and SFL in the coding of the data provided opportunities to track patterns of language functions and development of SEL skills. The verbal interactions of the interlocutor with the participants were analysed about their effect on the responses. The findings indicate the effect the interlocutor's language use in the development of creative outreach practices and meeting of SEL goals.

Nurturing social emotional learning through creativity

Over the last fifty years, Singapore's education has been transformed into a first world system of learning and for many in material and social well-being (Gopinathan, 2013). For a significant number of the Singapore population, the growth in overall academic success has translated into economic prosperity. As in all societies, also in Singapore there remains concern about people who for various reasons, such as fragmented family and disturbed community relationships, require assistance to achieve better social and economic life prospects. To break the poverty cycle, the foundation of the design of this creative program was to develop SEL skills to aid social participation. Although clear and measurable evaluation standards are crucial for program development and achievement of goals, the psycho-social dimensions of SEL are hard to measure concepts (Jones & Yudron, 2013). To date, no research has been able to pinpoint the exact causal relationship of play programs with achieving SEL outcomes. Contemporary creative practice based researchers (Connery, John-Steiner & Marjanovic-Shane, 2010) draw attention to Vygotsky's (1978) theoretical perspectives as an ontological entry point to understanding the mediating role of language, emotions and the effects of creative environments. These authors identify the strengths of playful settings and creative community programs and how meaningful verbal interactions and playful engagement made a significant and sustained impact on communities of children of different cultural backgrounds. Haas Dyson's (1995) examples relate to the dialogic nature of the responses of the interlocutor and bring awareness how children's use of creative activities and language support the social

awareness processes and participation. Social competence is characterized by the effectiveness of adult/child/peer social and verbal interactions and its effect on self-regulatory skills, emotional understanding and communication, social information processing and communication skills (Clegg & Ginsborg, 2006). Children do not develop these SEL skills in a vacuum but as part of complex ecological and cultural structures that include opportunities to practice these skills through dialogue. Halliday (1978) recognized the psychosocial nature of language. He (p. 2) notes how "by their everyday acts of meaning, people act out the social structure…" Affirming their social context, statuses, and roles, Halliday identified seven functions that language has to help children satisfy basic physical, emotional and social needs and children in their early years. Halliday calls them instrumental (use to get something); regulatory (use of control); interactional (establish relations); and personal (express opinions); representational (gives information); heuristic (questions environment); and imaginative (jokes, humour).

The method of analysis: Evaluating SEL through SFL

This study applies an ethnographic case study perspective and was conducted in Singapore as part of an evaluation of an outreach program for 20 children from families with low socio-economic status. The children's ages ranged from 4 to 7 years old and they had varying levels of (language) abilities and attendance. Although the play environment featured open-ended play materials, the initial art experiences were planned with a focus on similar artistic products. Observations indicated that some children struggled with the demands of the focus on the product. The outcomes of subsequent art experiences were revised to embrace a more open-ended nature. The phenomenon under investigation is the nature of the verbal interactions of the interlocutors and how the organizing concept of the various SFL functions of language can serve the development of SEL. SFL was used to analyse the relationship of the interlocutor's language with the development of SEL skills. The first part of the analysis examined the frequency and direction of verbal interactions to understand "Who interacts with whom and how often?" The second part used SFL to analyse "the nature of the interlocutor's verbal interactions with the children". Finally, the last part sought "an understanding of the influence of SFL language function on SEL". The data were collected through in situ videography and field notes of the program and consisted of five 3-hour play episodes and two full day 6-hour episodes. Trainee interlocutors were informed and consented about the research. Verbatim transcription of the video images facilitated the analysis. Table 1 provides some examples of the coding system. A more extensive coding system is available.

Table 1: Selected examples of coding using SFL approach

Coding First stage: Direction (UPPERCASE)		Coding Second stage: Selected Focus (lowercase)		Coding third stage: Selected SFL Functions (Italics)	
AI	Adult initiates	dodi	Demands object directed information	*I*	instrumental
AR	Adult responds	oodi	Offers object directed information	*R*	representational
CR	Child responds	api	Attention to personal ideas	*IM*	imaginative
CI	Child initiates	apa	Attention to personal affect	*IN*	interactional

The findings

The program was divided into 10 episodes. Episodes 1, 4, 5, 6, 7 and 8 were 3-hour sessions. Episode 2 and 3 were full-day 6-hour outings and counted as 4 episodes. Episodes 1, 4 of the program were facilitated by two trainee interlocutors (TI) with little knowledge of Halliday's language functions. Episodes 5 and 7 were facilitated by an experienced interlocutor (EI) with considerable experience with Halliday's functions. Episodes 6 and 8 were facilitated by the same TI but with in-situ mentoring. Episode 10 was a parent/child session which was not included in this part of the study. The initial episode 1 and 4 had a focus on specific artistic outcomes rather than SEL. The bulk of the interactions were adult initiated and left little room for children's initiatives. Episodes 2 and 3 showed a major shift in interactions among the children. Video images showed the children being reliant upon each other because of an unfamiliar environment and how this evoked interactions with a strong sense of community organisation. Episode 5 showed a change to more than 40% in child initiated interactions. This was repeated in episode 7. During episode 6, 7 and 8, the trainee interlocutors received in-situ mentoring and the focus of the artistic outcomes changed to a greater focus on the engagement processes. Although adult initiated interactions remained high, these reduced by more than 10%. With no change in the play environment, but with subtle changes in the language of the interlocutors, the frequency count and speech direction led to a deeper investigation of the SFL language functions and its relation to the outcomes of SEL.

Table 2: Frequency of interactions

(E = Episode)	E1 (TI)	E2/3	E4 (TI)	E5 (EI	E6 (TIM)	E7 (EI)	E8 (TIM
Adult initiated interactions	90	40	83	45	75	35	65
Child initiated interactions	2	5	2	20	20	25	25
Child/Child interactions	8	55	15	35	5	40	10
	100	100	100	100	100	100	100

The excerpt in Table 3 (episode 1) is the first example of the use of SFL. The trainee/ interlocutor (TI) uses a mystery box to create an entry point to achieve the goal of painting a group artwork. In spite of the friendly tone, TI's language and the words "I am" is directed to self. TI regulates and directs the children (FC = female child, MC = male child) to guess the content of the box. Interaction 4 showed how MC2's initiative to give information about himself was ignored. Instead TI continued to regulate correct object information. Although the use of a mystery box offered an opportunity to use imaginative language functions and garner information about the children's world, the language function of the question "What is that?" stopped TI from working towards SEL outcomes. During episode 4 there was a similar repeated focus on "What" and correctness.

Table 3: Episode 1 – Coding and analysis

No.		Text	Direction	Focus	Function
1	TI	(*Smiles and shakes the box*) What is in the box?	AI	dodi	*I*
2	MC1	A car.	CR	odid	*I*
3	TI	A car? I am not strong enough to hold a car (*shakes box again*).	ARN, AI	dodi	*R*
4	FC1	Toys.	CR	odid	*I*
5	MC2	(*raises hands*) I got toys in my…	CCR, CI,	api	*IN*
t	TI	(*Interrupts child and continues*) I got something in here (Opens a box) what is that?	AI	odid	*I*

The video data of episode 2 and 3 exposed the children's interactions and relationship to each other during their outings. Although the children were new to each other, their interactions evidence their recognition of each other as a community when in an unfamiliar environment. The visual data showed them staying close to each other, physically taking care of each other and ensuring each other's safety. The child/child interactions, albeit without much verbalizations, would have gone unnoticed if not for this study. Again adults' language was merely instrumental in regulating actions rather than nurturing ideas to provide information about self.

Episode 5 was facilitated by an experienced interlocutor (EI) who was new to the children. The theme of the lesson was "a wonderful world". The objective was to nurture ideas with children to could bring back a lost world. For comparison, the excerpt used as an example is taken from the same time frame as episode 1. EI gave each child a colourful plastic rock as "magic treasure". The aim was to create an entry point of what children could do with magic, and imagine and draw a world they thought was beautiful.

Table 4. Episode 5 – Coding and Analysis

No.		Text	Direction	Focus	Function
1	FC1	Close your eyes (EI holds hands in front of her eyes) and your nose (*laughs*) and your mouth (*laughs louder and moves the plastic coloured rock in her hands, she stretches out her hands*)	CI	Dodi, api	*R, IM*
2	EI	(Opens eyes and pulls face and pretends not to know)	AR	Odid, api	*IM*
3	MC2 MC3	(Join in and also stretches out his hand) You check with me.	CI	Dodi, api	*R*
4	EI	Oooh so much to guess (pulls a face and gives attention to each of the children by taking turns. The children wait) eenie meenie miney mo guess the hand that holds the stone (ticks each hand…)	AR	odid	*I*
5	FC2	(joins and *raises hands*) Where I got…	CCR, CI,	api	*IN*

The coloured rocks gave the children the tools and creative power to control and navigate their individual worlds. As make-believe tools, they allowed the children a playful engagement that encouraged initiative, practice self-regulation, and turn-taking. The use of spontaneous and improvised nursery rhymes

encouraged language use. Although the verbal exchanges were simple, different intonations in voice and actions such pretending not to know, helped the children to explore ideas and extend their use of language in used a more a rich and descriptive language. EI's pretending not to know, mediated SEL goals and gave children the opportunity to take charge. The acknowledgement of "so much to guess" brought a shift that allowed the children to negotiate. Imaginative functions are important in creativity and give entry to a world that is open to personal ideas (Connery et al., 2010).

Table 2 indicates that although adult initiative remained high in the TI led episodes, the descriptive nature of responses evidenced the relationship of change in TI's interactions to SEL goals. Opportunities to review the videos and in-situ mentoring brought for the TIs an opportunity to practice new language skills. Reflections about the nature of their interactions encouraged them to let the children be in control. Providing the children with greater opportunities to explore ideas evidenced a shift in the children's language and nature of interactions which related to SEL goals. Expressions such as "I (also) can", "we like", "I made this by using…" and "Can I make…" evidenced confidence, self-awareness and risk-taking. The visual data further evidenced the effect of changed nature of the TI's responses. As the TIs reflected on language functions and reduced their focus on "what is this" to "oh, I wonder how you did this", their verbal responses invited children to thicken their expressions and explore social relationships among themselves, family and community.

Conclusions and implications

The focus of this study was to design evaluation standards that can bring accountability to program goals. Halliday's (1978) SFL was at the base of an analytic framework. The video data assisted the analysis and evidenced the relationship of verbal interactions with SEL goals. Descriptive qualitative differences in speech acts were found between episodes facilitated by the trainee interlocutors, the trainee interlocutors with mentoring, and the expert interlocutor. SFL identified how during the initial episodes the trainee interlocutor's verbal focus was on regulation, rather than SEL skills and carried the risk and possible dangers of "over-regulating" rather than self-regulating. In-situ mentoring and attention to the frequency, direction and function of the speech acts brought an understanding of the relationship of language functions with program execution and the objective of achieving SEL goals. Although the selected examples are limited, the nature of the verbal responses induced ideas how the interlocutor's responses may affect children's development and SEL goals. SFL also brought attention that what occurs in programs may be clouded by a traditional focus on assessment of the child only, rather than the child's development as a response to the facilitator's speech acts. Although more in-depth studies are needed, theoretically and methodologically, the application of SFL as part of coding framework adds to current research about the role of the interlocutor. The findings initiate ideas about the role of language in the evaluation of creative program outcomes. The use of SFL in evaluation and relationship to SEL goals may be of interest to a variety of audiences ranging from policy makers, researchers and to practitioners in diverse program settings and may include other contextual dimensions.

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Understanding Teacher's Principle-Based Practice in Sustaining Knowledge Building Practice in a Science Classroom

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Abstract: In this paper, we trace one teacher's attempt to design knowledge building classroom in a principled way for a class of low achievers. Through the narrative of teacher's effort in planning, enacting, and reflecting on knowledge building practice, we hope to provide a perspective for practitioners to construct 21st century teaching and design capability. Understanding teachers' work in their natural setting is important in encouraging a culture of learning designers among teachers; one that centers around students' thinking and learning more than teachers' judgment. Such a principle-based approach relies on teachers' interpretation of Knowledge Building principles and their translation of these principles into daily practice. As the idea of teachers as designers of learning is rather under-represented in practice, we hope such reflective journeys will provide a lens to other practitioners and challenge the notion that such a principled-based approach is only theoretically sound and has little practical value.

Introduction

There has been a significant effort to shift from individual inquiry to collaborative inquiry in educational approaches so that student learning remains vibrant and robust, thus ensuring that they are ready to face the challenges in this world of rapid change and technological advancement (Scardamalia & Bereiter, 2006). Although the 'why' of the shift is clear, many teachers still grabble with the 'how'. In recent years, we have seen an extensive professional development effort aiming to prepare teachers to embrace such a shift while continuing to be efficient and effective in their work. In this paper, we trace one teacher's attempt to reflect and design knowledge building practice in a principled way in a class of lower ability Science students. Through the narrative of teacher's planning, enacting and reflecting, we hope to provide a glimpse into 21st century teaching competencies and ways to develop teachers' design capability.

Teachers' role in a KB classroom

KB practice involves teachers making decisions that move towards fostering and sustaining a knowledge creation culture that supports creative work and continual improvement of ideas. Teachers have to think about the kind of interactions in their classes that puts students' ideas at the center of the classroom enterprise (Scardamalia & Bereiter, 2003). Teachers also have to rationalize and translate their teaching practice in relation to Knowledge Building principles (Scardamalia, 2002) which characterize an interactive system that makes continual improvement of ideas possible. Apart from these efforts directly relating to translating KB principles, teachers also have to adapt teaching strategies according to their students' diverse needs and academic backgrounds, and provide students with sufficient guidance to engage their heart and mind in knowledge building processes (So, Seah & Toh-Heng, 2010).

Knowledge building in a science classroom

Many studies have undertaken the task of implementing knowledge building approach in the teaching and learning of science topics. Research has demonstrated that students of all ages can work as knowledge builders, e.g., when students are given opportunities to attempt problems of understanding that they are interested to explore, they are able to work through the problems to derive good explanations. All of which characterises deeper inquiry in science (Zhang et al., 2007; Scardamalia & Bereiter, 2009; Chuy et al., 2010). Although research has shown that knowledge building pedagogy benefits both high- and low-achieving students (So et al., 2010, Niu & van Aalst, 2005; and Chan & Lee, 2007; So et al., 2010), there still exists a general belief that low ability students do not have the cognitive foundation to navigate in such an environment. This misconception of students' knowledge building ability is generally mirrored in an examination of existing literature on teachers' beliefs, practices, and competencies.

Narratives of teacher reflecting and designing a KB classroom

This case study traced the work of a teacher who has six years of teaching experience and two years of Knowledge Building experience over a 5-week period. He has been working with Normal Technical (NT) classes for all his years as teacher. These NT students are the lowest scoring cohort in the Primary School Leaving Examination and deemed to be less inclined academically. Their secondary education mainly prepares them for further vocational and technical training at the Institute of Technical Education (ITE). Based on his experience with this group of students, the teacher was initially hesitant about adopting KB approach on the topic of "Food Matter" due to time constraints. However, after he discussed the values of science education with his Head of department and the researcher, he decided to try to prioritize the "developing of thinking about science" (as he put it) rather than the delivery of content in his NT class this year. He felt that this goal matched with that of the KB approach.

Getting started

For the first lesson, the teacher started off by sharing some basic knowledge on the topic on Food, followed by a classroom discussion on the topic. The discussion was done solely in class and captured by the teacher on the whiteboard. This brainstorming on "Food" raised some interesting questions such as "how is food important?" and "how is food made/ created?" With knowledge building principles of real ideas and authentic problems in mind, the teacher was careful not to dictate the content so as to allow students' ideas to take precedence in the classroom. He later reflected that he was pleasantly surprised that the students already knew quite a bit in the textbook and that they were able to recall the facts from textbook.

Shaping ideas through experiment and discourse

In the second lesson, the teacher felt that more information was needed to develop his students' ideas about food so he introduced a series of experiments on food testing and got students to talk about these experiments. A student managed to connect starch observed in the experiment to their discussion on 'plant being the largest producer of food' in the previous lesson. The class subsequently became interested in the growth of plants as a source of food producer. This interest led to a discussion on environment when the idea of soil acidity was introduced. Students verbalized their ideas on acidity in soil and the teacher wrote their ideas on the whiteboard. He then got students to take down notes about the discussion in their own journals. Throughout this, teacher actively modeled note-taking and active-listening. He realized, in retrospect, that "the NT students started to ask question that Express students would not ask", he described that as his turning point in the way he was determined to design the lessons the knowledge building way.

Extending discourse in class to include online platform

At this point, the first Knowledge Forum (KF) View was created to get students to pose their ideas online instead of simply voicing them out in class. The transition to the online platform was fairly seamless because students were eager to extend their classroom discussions. Thus, students' ideas came forth quite quickly at this stage.
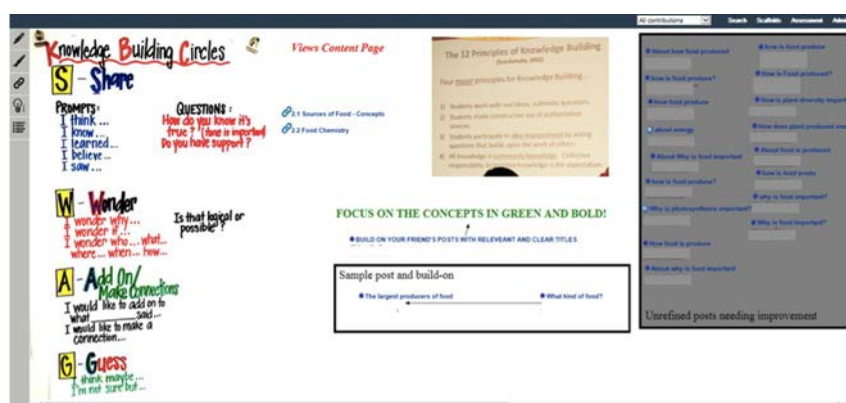
Figure 1. First Knowledge Forum View for the students.

The teacher explained that since KB teaching method is not one size fit all, different teachers have different styles and different classes have different needs. Based on this thought and as he thought through what has taken place in class so far, the teacher decided to get students to move away from textbooks and express their understanding through journal and notes to complement their idea sharing on KF. Further, to make sure that students are motivated to journal their learning, he decided not to provide additional notes to students and instead,

get them to use their own journal for revision. Hence, throughout these lessons, whenever students asked him for teachers' notes, he replied that the textbook is sufficient and that they (the students) should be the ones creating their notes for revision.

Redesigning scaffolds to sustaining idea improvement

In planning the third lesson, the teacher noted that the questions posted by students on KF were not good enough as students didn't understand how to use the scaffolds. He decided to redesign the scaffold to make it more understandable to and accessible by his students. He found a resource online that unpacks the original knowledge building scaffolds into active phrases. For example, this new set of scaffold has four sentence starters; "I think", "I learn", "I know", "I believe", "I saw" versus "My theory" in the original KB scaffold and "I wonder why", "I wonder if", "I wonder who…what…where…how" replacing "I need to understand". The new set of scaffolds seemed to work, but the teacher soon realized that students' questions posted online were quite similar (lack of idea diversity needed for knowledge building). Hence, he decided to give them more time to shape their ideas. He got students to first jot down their ideas in their journals, then read the notes on KF, and subsequently post a different or improved ideas on KF. He also got students to focus on writing meaningful titles for their notes in an effort to get them to think about their post.

In one of the subsequent KF views titled 'Sources of Food - Concepts' (refer to Figure 2 below), students posted notes and built on others' notes while teacher made use of these notes to conduct a class discussion in which students brought up multiple ideas, such as mass production and how cities are made. Students also brought in relevant information on agriculture that they had learned from watching National Geographic.
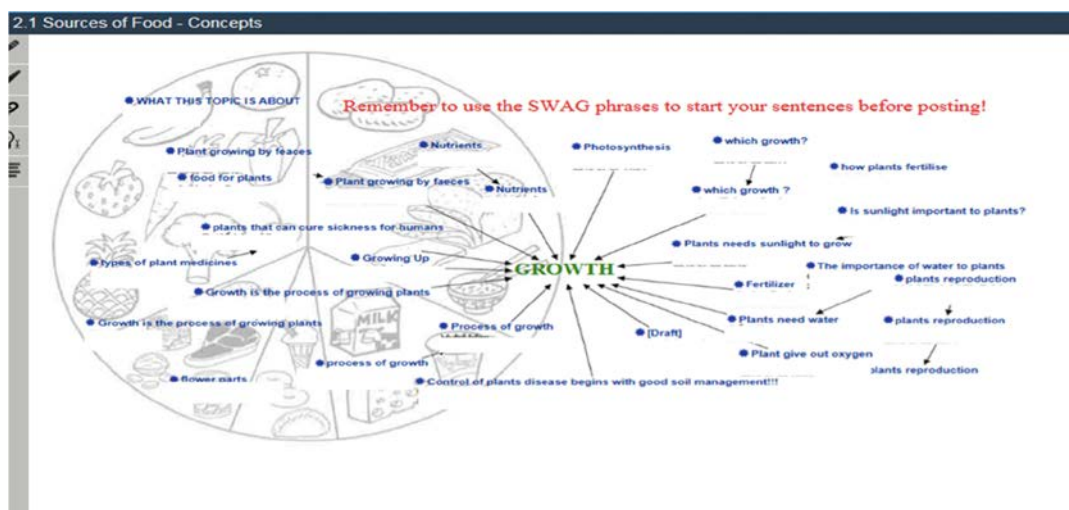
Figure 2. Knowledge Forum view titled Sources of Food–Concepts.

When one student posted, "I wonder how fertilizer helps plant grow faster" and "how do you improve food production", the teacher seized this opportunity to start a class discussion about fertilizer. Students responded with a multitude of perspectives on fertilizers, e.g., a danger to health. He then showed the class two sets of videos as resources for students to watch and deepen their understand of the points discussed in class.

The teacher felt that there was a deeper understanding of this topic for the students this time round. Students were particularly interested in the video of slash and burn as Singapore was then undergoing a period of haze caused by such actions in Indonesia. The teacher utilised this interest and got students to research online on the two topics (fertilizer and slash and burn) and the question ("how do you improve food production"), and to post their information gathered on a new KF view titled "Soil Fertility".

Embedded assessment

Before the final lesson in this series of KB lessons, the teacher worked with the researcher to design questions based on a new scenario of a group of farmers living near volcanoes and got students coming together to reason out the scenario. Students sat in groups of three to reason out the case in Indonesia where farmers continued to stay close to active volcanoes. Many were quoting what they understood about slash and burn, soil, farmers' needs, etc., to explain the situation. They were also talking about the danger of the lives of farmers as they

rationalized the scenario. Upon reflection, the teacher felt that students were displaying critical and global thinking which was quite rare for this group of students, as seen in their past performances. Results from this exercise showed that the students were able to accurately surface key ideas, pull out information, and even connect information from the various discussions in class and on KF to explain the phenomenon. The explanation might include naive understanding but the teacher reflected that he was surprised at the reasoning the students displayed in their response to the questions which he has not seen before. Below are abstracts of the students' interview.

Student 1: What if their house is not close, but their plant is close. They cut and harvest and it become(s) the new fertilizer. Some volcano has certain timing. The one in Surabaya, the tour guide told me there is a timing every year.

Student 2: That maybe the reason because lava is hot, maybe the farmers' plant needs heat. Oh wait! the smoke is carbon dioxide right? So the plant takes in carbon dioxide and take(s) out oxygen.

Student 3: The ash maybe fertilizer, we take like the slash and burn example, those remaining burn parts become the fertilizer. The burn from the slash and burn.

Rise above

As a final activity, teacher printed all of students' notes in the 'Soil Fertility' view. He got students to review one or two notes each, then put the notes up on the classroom wall to build a collective whole-class learning artefact based on the overarching theme of 'yield'. After the activity had been completed, the teacher led an entire class discussion to get students to connect and synthesize ideas.

Conclusion

The dynamics of a knowledge building classroom is highly dependent on the interaction between teacher and students. In this study, the teacher's role was largely that of providing time and space for students to inquire and explore their ideas on KF, and advancing knowledge along with them. He also carried out the critical task of developing lessons which encouraged inquiry processes and supported collaboration amongst students. His lesson design incorporated a principled way of designing a trigger activity (experiments on food testing and soil acidity), and providing opportunities for contribution (creating new KF views and coming up with scaffolds), as well as space for collaboration (classroom discussions to allow students the opportunity to voice their opinions).

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Knowledge Building for Students With Low Academic Achievement

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Abstract: This paper describes a Hong Kong teacher's experience using knowledge building and Knowledge Forum® to address the learning needs of students with low academic achievement. Contrary to what most teachers would expect, even low-achieving students respond well to knowledge building, and their discourse is of high quality compared to that obtained in other knowledge-building classes in Hong Kong. The paper provides an account of how the teacher used the knowledge building approach and his reflection on pedagogical principles as well as the relevance and feasibility of learning-sciences approaches like knowledge building in ordinary schools, where students lack academic skills and motivation.

Introduction

Instructional approaches developed by learning scientists such as knowledge building and project-based learning emphasize active and interactive learning, metacognition, and student agency (Kolodner et al., 2003; Krajcik et al., 1998; Scardamalia & Bereiter, 2006; Slotta & Linn, 2009). These methods take more time than direct teaching (i.e., presentation of concepts and worked examples, followed by practice), and are therefore often regarded as not feasible for most students. The two arguments against them made most often by teachers are that it is impossible to teach this way due to examination —an important issue in Confucian-heritage cultures where examination performance defines educational success—and that only high-achieving students are capable of the necessary agency, collaboration, and metacognition. These common beliefs prevail despite the fact that many approaches have been developed in inner city schools with a wide range of student abilities and interests, and research showing that students with below-average achievement can benefit (e.g., White & Frederiksen, 1998). Such beliefs generally make it difficult for teachers to try out classroom innovation.

I teach in a Band 3 secondary school in Hong Kong. (Note: First person is used based on the first author's experience as a knowledge-building teacher). Secondary schools in Hong Kong are divided into three bands based on student performance in examinations at the end of elementary school determining to which secondary schools students are admissible. In a Band 3 school most students score in the bottom third. These students are weak in English, Chinese, numeracy, thinking, communication, and have low motivation and self-esteem. For these students direct teaching is ineffective; instead they require "learning by doing." The students I am teaching in my class primarily have academic difficulties for a number of years in their schooling.

I have developed teaching approaches based on knowledge building for eight years in my Visual Arts courses—including collaborative inquiry, classroom discussion using visual displays on the classroom walls, online discussions in Knowledge Forum (KF), and student-directed reflective assessment of KF discussions. In this paper, I describe why I use knowledge building and share my beliefs about knowledge building for low achievers. In discussing these experiences, I work with my collaborators to explore the relevance of knowledge building in ordinary schools other than some approach that is only relevant for elite schools. As I understand, among the instructional approaches in the learning sciences, knowledge building is rather complex and many modifications to the classroom environment and pedagogy are needed. Many teachers would believe that we should make things simple for low-achieving students. But for the students with whom I work with, knowledge building may instead be an advantage since conventional methods or the so-called inquiry approaches in schools may not be effective with them. Examining how knowledge building approach works for low achievers from a teacher perspective may be important as it may be applicable to other learning sciences approaches.

What is knowledge building?

Knowledge building is an educational model that is known well in the learning-sciences community, so only a brief description is needed here; according to Sawyer (2006) it is one of the foundations of the field. One of the most important features of knowledge building is a shared goal, in a community (usually the class), that aims to advance the state of knowledge in that community. Thus, everyone works to advance the community beyond what it collectively already knows. According to Scardamalia and Bereiter (2006) knowledge building is "an attempt to refashion education in a fundamental way, so that it becomes a coherent effort to initiate students into a knowledge creating culture. Accordingly, it involves students not only developing knowledge-building competencies but also coming to see themselves and their work as part of the civilization-wide effort to advance

knowledge frontiers" (pp. 97-98). Other important features include epistemic agency, constructive use of authoritative sources, and the "democratization" of knowledge (Scardamalia, 2002). In short, knowledge building enables students to create identities as people who are capable of creating new knowledge and contributing to the knowledge base of a community. Of course, this does not mean that students achieve groundbreaking advances that are unknown to the world; rather they see their own advances as historically significant. "Mendel worked on Karen's problem," as Scardamalia has often put it. Knowledge building involves "discourse;" indeed, in knowledge building theory, discourse is both the method and product. Knowledge-building discourse occurs in the classroom and in Knowledge Forum. Interestingly, when James Banks once spoke at a local university on what American education needs in order to engage youths who feel disenfranchised by school, from perspectives of race, culture and opportunity, he used terms such as "democratic knowledge" that resonate with knowledge building theory.

Why knowledge building for my students?

The ideas of knowledge-building highlighting community and democratizing knowledge suggest why it may be a good approach for low-achieving students. For me, it offers something new for them, who are achieving little and are disengaged by what school offers. Knowledge building, rather than being concerned only with catching up with what is already known, provides an opportunity to *create* something—new insight into an important question. It seems relevant to Visual Arts education, which aims to help students make creative work. But when I first tried knowledge building in my class it was not because of such lofty ideas; it was because nothing else seemed to engage my students. Perhaps knowledge building would engage my students.

As a visual arts teacher, my philosophy is to have students take up and develop what they would like to do, even if they are high or low achieving. Many Visual Arts teachers would ask students to design a park and then there would be fifteen designs for parks. I would much rather have students come up with their ideas, and we then work together to develop their ideas; I work with the students to see how far their ideas can go. So when I encountered knowledge building emphasizing student agency, this model appealed to me because it fits well with my own beliefs. I hope my students can take charge of their learning and creation, deconstruct information and then rebuild their knowledge. Similar to how they study art pieces, they construct their visual elements, find out relationships, and construct theories about their creations. These features are important in the New Secondary School (NSS) curriculum for Visual Arts, which emphasizes 21st century skills and a conceptual approach to studying art. For example, the NSS Visual Art Curriculum requires our students to achieve four goals: 1) developing creativity and imagination; 2) developing skills and process; 3) cultivating critical responses; and (4) understanding arts in context.

One of the most impressive experience I have had is that one of the weakest students in my class, who had learning difficulties and was socially isolated, became excited about writing through knowledge building and he even won a writing award . In my early years of using knowledge building, I had a student called James (pseudonym), an isolated and silent student for years, and most teachers thought he had learning disabilities and he would not be able to do much in school. James was generally ignored in class by teachers and peers. But when I started using Knowledge Forum, James started to write a few notes and then more and he liked it because he said he had more time to think about his ideas than what usually takes place in class. His classmates also liked his ideas as they are helpful and he gradually gained some respect among his peers. James became very interested in writing and contributing his ideas. During that semester, he took time each day during lunch time to do more writing and contribution to Knowledge Forum and he seemed to enjoy that much. Over time, he improved on his writing and confidence and he entered an inter-school writing competition and won a prize (see vignette reported in van Aalst & Chan, 2012). I did not expect much in the beginning but with James and other students working on knowledge building, I came to understand more about my students and that even low-achieving students could do much given the appropriate learning environment.

Pedagogical designs and results

Guiding pedagogical principles

My teaching of students with low achievement is based on the following principles:

1. My students have difficulty in interpreting the meaning behind the text so the curriculum need to be rich with video and photography.
2. My students have poor communication and thinking skills, but they can still benefit from a variety of scaffolds prior to working on KF, such as the Knowledge Building wall (described later), knowledge building conversations, and scaffolding group work and inquiry tasks that address

curriculum goals.

3. Most of my students lack motivation, so it is useful to let them have experiences and tasks that they can accomplish, to let them enjoy success and to sustain their interest; students' poor self-esteem can be changed when they experience success and progress.

4. Knowledge building principles (Scardamalia, 2002) such as idea diversity, collective responsibility for community knowledge, and improvable ideas can support student work and creativity.

5. Knowledge building provides an error-free environment for students to pursue their understanding. Knowledge-building discourse, with its emphasis that "all ideas are improvable" helps low-achieving students to be comfortable in an error free environment. Knowledge Forum thus provides an open space for students to work on their ideas freely and to keep track of their growth.

Community art unit: Initiating students into inquiry

One of the units I have students do is to investigate an old village in Hong Kong. At first I thought that they needed to read something before they can engage in knowledge building, but I found they cannot learn very well from document or books. Thus, I reversed the process: I asked them to go into the village doing some investigation; for example, talking with the village people, and then taking some photos and doing some drawing. After that, back in class, students did some investigations based on their experiences to figure out what is happening in the village; students then used their knowledge and created an exhibition for their neighborhood to show what they found out in the village. In the second semester, we continued with such inquiry and used Knowledge Forum to discuss what community art is and to explore the relationship between community and art using their knowledge and experience from the village visit. This design led to a substantial improvement in the quantity and quality of writing on Knowledge Forum. This unit enables students to work on a project that is engaging. It hones their collaboration, work with ideas, communication with an authentic audience, and eventually extensive writing and reading on Knowledge Forum.

Knowledge-building wall and ideas made public

Knowledge building in my classroom is not only about Knowledge Forum. For students with low achievement, it is helpful to start with something more authentic; as described above, students learn from the field-based process; they are self-directed to some extent, and hone inquiry and collaboration skills. Regarding discussion of their ideas, we spend considerable time creating a "Knowledge Wall". This is a visual representation of the class's ideas using index cards and strings. This is a well-known strategy for promoting collaborative classroom talk and has been used in many knowledge-building classrooms (Chan, 2011). The knowledge wall helps low-achieving students to understand the public nature of discussions in knowledge building; is easier to start; and is a visual display of the class's shared ideas—it is visually and physically present in the classroom. The knowledge wall supports the notion of "ideas made public" that knowledge building requires (Fig. 1). However, over time, it becomes too difficult to maintain when there are multiple discussions and too many ideas, and Knowledge Forum is usually introduced at that point but the Wall provides good bridging for my students.

Figure 1. Working at the Knowledge Wall.

Knowledge building and reflective assessment

Another major development in my teaching pertains to the use of reflective assessment with the class assessing their own work on KF. Initially this consisted of running the Analytic Toolkit and Applet tools that accompany KF to measure the number of notes written and read, together with other contribution per student, and my students responded enthusiastically to the concurrent feedback. I have also included summary notes to help them synthesize knowledge and recently I have collaborated with Yang in her thesis research and have used the Knowledge

Connections Analyzer (van Aalst et al., 2012). Prompt sheets were used alongside with the tool to help them gather information about class collaboration and interactivity and then they discussed the results in small groups and reflected on progress. Using this tool appears to help students understand the nature of their discussions from a knowledge-building perspective (for details, see Yang, van Aalst, & Chan, 2016).

Reflection and brief indication of results

While knowledge building has my students to be more creative, I found it is also beneficial in preparing them for examination when they need to interpret art pieces and write explanatory prose, and such tasks are very difficult for low-achieving students. The experience of writing on Knowledge Forum and working with ideas and building on others' questions has helped them develop more competence and confidence. I think my strong beliefs in the approach and in my students has helped to sustain my practice over the years. Working with my collaborators, I also list some brief results: (1) Students contribute actively and the quantity of note writing and reading is better than average in comparison to other knowledge building classes in high-banding schools. (2) There is a good balance between fact-oriented and explanation-seeking notes in KF discourse. (3) Analysis of discussion threads based on the framework (van Aalst, 2009) shows that my students are writing high-quality discourse not just sharing information (for details of empirical findings, see Yang, van Aalst & Chan, 2016).

Concluding remarks

In this paper, I have shared my beliefs and approaches using knowledge building for students with academic low achievement. I believe that knowledge building approach emphasizing improvable ideas and community growth has potential for students with low achievement who have disengaged themselves from the education process. I hope my experience provides a useful message for the uptake of knowledge building and other learning-sciences approaches that bear family resemblance to it for students of different abilities. While there are still many challenges and barriers, I believe that knowledge building offers new possibilities and we can continue to ask questions to develop improvable practice as knowledge-building teachers.

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Developing Students' Early Science Literacy – A Holistic Approach to Science Learning

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Abstract: This paper focuses on one of the lesser known dimension in science education. It provides a platform for educators to examine the effectiveness of integrating science with English language to develop students' initial Science concepts. It examines the relationship between experience, knowledge and application in lower primary students before formal science education. Students are provided with authentic experiences to support science learning as well as the Modified Language Experience Approach (MLEA). As part of informal assessment, students will actualize their science learning through outputs during the pre-writing and production stage. Finally, we discuss the implications of our programme for early Science literacy as part of holistic education.

Introduction

Education in Singapore focuses on striving to provide students with a holistic education. Holistic education is about nurturing the whole child and providing a rich diversity of learning experiences for our students (Ministry of Education, 2015). In the provision of interdisciplinary approach towards students' learning, Allen (2008) mentioned that it helps to develop their critical thinking and cognitive development through the acquisition of different forms of knowledge. The students will focus on learning the big idea during science lessons and transfer the concept to their English lessons.

According to Kolb's Experiential Learning Theory (Kolb, 1984), experiential learning is the process whereby "knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience." Students are actively involved in their learning through concrete experiences, reflective observation and abstract conceptualisation. By integrating science across disciplines, experiential learning can be captured through meaningful formative assessment when they apply the science concepts in their writing. In addition, elements of 21st century competencies including communication and collaboration are incorporated in the model as shown in Figure 1. By integrating multiple layers of meaning and experience in the students' learning environment, we adopt a holistic approach to develop students' early science literacy when extend their learning beyond the classrooms.
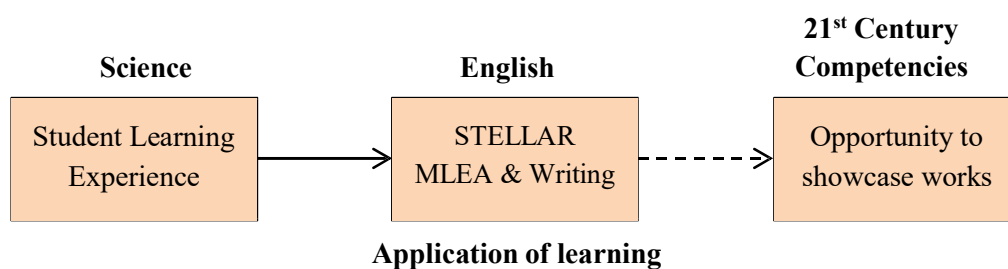
Figure 1. Model for inter-disciplinary approach towards early science literacy.

Methodology

The sample size for this study was four primary two classes of mixed abilities. To reduce biasness based on gender, the sample size consisted of both male and female students.

In prior research, Behrendt and Franklin (2014) mentioned that field trips motivate students to make connections between the theoretical concepts in the classroom and what has been experienced. A field trip was designed to support MLEA with a shared experience as well as develop students' learning of science concepts through integration.

Before the field trip

Primary two students were introduced to the non-fiction big book, A Butterfly Is Born, as part of the Strategies for English Language Learning and Reading (STELLAR) programme. The book was read twice; first reading was for enjoyment and followed by second reading for understanding. Students learnt the vocabulary used in the big book and completed the STELLAR worksheets over the period of a week.

During the field trip

Four primary two classes of mixed abilities were selected to go on a field trip to the Singapore Science Centre (SSC). They were provided with comprehensive hands-on experiences such as examining live specimens including cicadas, caterpillars, pupas and butterflies. During the session, students were expected to achieve the following learning outcomes: to differentiate between insects and non-insects and to identify the characteristics of an insect, to learn about the different parts of an insect and the life cycles of insects. The process skills involved were observing, comparing, classifying and communicating through meaningful conversations. Lastly, their learning at the SSC was consolidated with art and craft activities.

After the field trip

Using the experience from the SSC, students followed up with group writing during their English lessons. English teachers facilitated the two period English lesson as students engaged in group discussion during the prewriting stage, drafting and production stage. The programme was concluded with recess activities to involve other lower primary levels. A gallery walk was set up to showcase some live specimens and for students to showcase their MLEA writings.

The quantitative phase of the study included collecting students' artefacts. Students' learning from the field trips were captured in their writings. Qualitative observation data were also collected through video recording of the MLEA writing lesson. The results shed some light on how students' early science literacy can be developed through integration.

Findings

Quantitative data

Data derived from the sources outlined in the method were analysed. Six artefacts were used as samples (S1 to S6) to fuel our findings. It was observed from the six samples that many of the vocabulary words that were taught during the English vocabulary lesson were used. The words that were taught during the vocabulary lesson are 'beautiful', 'butterfly', 'branch', 'caterpillar', 'flower', 'nectar', 'pupa' and 'tongue' (taken from STELLAR specific guidelines: A Butterfly is Born).

The quantitative data showed that the frequency of scientific words and concepts were high. For the first activity, students were taught explicitly on how to determine whether an animal was an insect. They made comparisons between a spider and an ant.

Table 1: Use of scientific concepts on insects

Scientific Concepts	S1	S2	S3	S4	S5	S6
Comparison	✓					
Has six legs	✓					
Has feelers				✓	✓	
Has three body parts	✓	✓	✓	✓		

Many of the samples used some scientific concepts about insects (see Table 1). They highlighted that an insect should have three body parts. Sample one extended their learning by discussing how they differentiated between an insect from a non-insect. However, sample six did not make use of the scientific concepts from the first activity. This could be due to fewer members in the group, hence resulting in lesser contribution of ideas.

The second activity is where students were scaffold to label the different parts of a butterfly. The words that appeared in the worksheet are collated into a table. We tabulated the frequency of the scientific words appearing in the different samples as shown below.

Table 2: Use of scientific terms on insects body parts

Scientific Terms	S1	S2	S3	S4	S5	S6
Feelers				1	1	
Legs	1			1	1	
Head	1		1	1	1	
Thorax	1		1	1	1	
Abdomen	1		1	1	1	
Wings				1	1	
Proboscis				1	1	
Exoskeleton	3	2	3	1	1	1
Cicada	1	2	1			
Feelers				1	1	

The term 'exoskeleton' was used extensively in students' writing with some groups using it more than once (see Table 2). Students tend to use 'exoskeleton' in context more frequently than 'cicada' because they have touched and examined the exoskeleton of the cicada. They did not have the chance to experience the actual cicada. According to George (1991), learning is an active process in which the learner uses sensory input and constructs meaning out of it. By engaging the students to explore using their senses, it leaves a deeper impact on the students.

For the third activity, students are tasked to stamp the different stages of the life cycle of a butterfly and a dragonfly.

Table 3: Use of scientific concepts on life cycles

Scientific Concepts	S1	S2	S3	S4	S5	S6
Use the term 'life cycle'	✓		✓	✓	✓	✓
Show understanding on the transition of the different stages in the life cycle of a butterfly	✓					✓

The term 'life cycles' were mentioned in almost all the samples (see Table 3). Samples one and six had students drawing out the entire four stages life cycle of a butterfly. Even though life cycle has not been taught explicitly in the STELLAR big book, students were still able to incorporate the science concept into their writing. Students were presented with caterpillars, pupa and butterfly specimens during the lesson. There is a transfer of learning from concrete to graphical representation through the stamping of the different stages of the life cycle in sequential order.

Qualitative data

Qualitative data were collected in the participants' classroom to examine student-student and student-teacher interactions through video recording of the MLEA writing lesson. It was observed that the students take ownership and feel empowered to participate in group discussions. There was frequent use of scientific language as students were generating ideas. Teachers took on the roles of being a facilitator and students engaged in meaningful group conversations.

Conclusion and implications

To sum up, this paper looks into a lesser known dimension for educators to consider – developing students' early science literacy through integration. Integrating science with English language facilitates the acquisition of early science literacy. The shared field trip experience provides the context and content for discussion. Students were observed asking and responding to more science-specific questions as they construct meaning out of their experience. This becomes the basis for group writing which supported both science and English language learning as students record their observations.

Ellenbogen, Luke and Dierking (2004) cited in Behrendt and Franklin (2014) highlighted that effective field trips should be an integral part of every science programme. Students are motivated and show understanding of science concepts when they engage in hands-on activities. In addition, the recess activities serve as a good platform for the students to showcase their learning experience. This opens up opportunities to nurture students

holistically and engage them through the rich diversity of learning experience.

Looking forward, teachers are interested to look into extending this programme to all primary two classes and to include other STELLAR non-fiction big books across levels. Teachers are also keen in examining students' knowledge retention as they progress to upper primary levels.

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Workshops

Towards Next Steps for the CSCL Community: Advancing Science and Informing Real World Collaboration in Web 2.0

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Abstract: The CSCL community is at a crossroads -- at the brink of new paradigms in theories, methods, and forms of support, as new opportunities for impact in the expanding Web 2.0 space present themselves. As a community, we must find a strategic footing within the changing landscape. We need to advance and integrate new theories, methods, and supportive technologies. To that end, one goal of the workshop is to identify cross-cutting themes in CSCL research related to alternative Web 2.0 platforms. Another goal is to identify a strategic positioning for research in CSCL in synergy with the HCI/CSCW literature.

Introduction

The CSCL community is at a crossroads -- at the brink of new paradigms in theories, methods, and forms of support, as new opportunities for impact in the expanding Web 2.0 space present themselves. As a community, we must find a strategic footing within the changing landscape. We need to advance and integrate new theories, methods, and supportive technologies. To that end, one goal of the workshop is to identify cross-cutting themes in CSCL research related to alternative Web 2.0 platforms. Another goal is to identify a strategic positioning for research in CSCL in synergy with the HCI/CSCW literature.

Historically, prior to the rise of Web 2.0, the field of Computer Supported Cooperative Work encompassed collaboration broadly, including both learning and work. However, over time differential concerns related to learning and work led to division between communities. On the positive side, the CSCL community was birthed, matured, flourished, and has made important advances over time. Nevertheless, the split has also resulted in missed opportunities. With the rise of Web 2.0, the commonality of concerns between communities has increased, however, communication between communities has not kept up with this shift. With the recent rise of the MOOCs, the overlap in interests has grown still more, and yet the fragmentation between subfields continues.

In this highly interactive workshop, we will have invited presentations, panel discussions with audience participation, and poster sessions. Each participant is invited (but not required!) to bring a poster related to one of the three workshop themes: Collaboration in Social Networks, Collaboration in Work Communities, and Coordination and Self-Regulation in Online Learning Communities.

The workshop will be divided into three segments. In each segment, two presenters will talk about their work in the Web 2.0 space, emphasizing vision for future work. Each of these presentations will focus on a different Web 2.0 space. The talk will be followed by some discussion and then a panel comprised of an expert in theories, methods, and collaboration support. The panelists will act as discussants for the presentations as well as offering their own view more generally of how the field should advance in the areas of theories, methods, and support.

Session 1

Collaboration in Facebook

Dimitra Tsovaltzi will present a series of studies on argumentative learning in Facebook that attempt to extend CSLC principles to learning in Social Media. Awareness tools depict group information and aim at leveraging socio-motivational aspects of Social Media. Argumentation scripts offer cognitive support and aim at fostering quality argumentation. Together, they can be attuned to provide a subtle but effective support in Facebook over longer stretches of time. However, the effects of such standard CSCL instructions do not always carry over to Social Media, where social aspects like trust and self-presentation become prominent.

Collaboration in Gaming Communities

Yasmin Kafai will present analyses of participation in a tween virtual world combining big data approaches (i.e., cluster analyses of large player groups) with thick data approaches (i.e., ethnographies of individual players and practices). This type of rich data analysis illustrates how we can study learning across online and

offline contexts and examine what each approach can contribute to our understanding of learning.

Panel: Susan Yoon (Theories), Heisawn Jeong (Methods), Peter Reimann (Support)

Session 2

Collaboration in Wikipedia
Ulrike Cress will present her co-evolution model describing how people collaborate with social media. She will present some experimental work based on that mode and some studies using social network analysis of Wikipedia data

Collaboration in Scratch
Deborah Fields brings together two studies on online websites for children. First, a comparative analysis of over one hundred websites where children can share things that they make and what this reveals about designers' neglecting to provide key forms for social sharing online. Second, consideration of site-wide distributions and patterns of participation that illuminate the relevance of different online social practices to ongoing involvement in the Scratch online community, one of the most richly designed DIY communities for kids.

Panel: Sten Ludwigsen (Theory), Jun Oshima (Methods), Jim Slotta (Support)

Session 3

Carolyn Rosé and Dragan Gaesevic: Collaboration in MOOCs
Rosé will describe a 3 part data-to-support pipeline developed collaboratively with Gaesevic in order to support goal directed learning progressions in a Facebook-like social layer called ProSolo that can be integrated with MOOC platforms like edX. The talk will illustrate how the analytics end of the pipeline reveals that students benefit from observing effective goal directed learners, but rarely find and follow them without support. The support end of the pipeline is able to suggest role models to fill the gap.

Sean Goggins: Coordination in online communities
Goggins will describe his Group Informatics methodology and ontology for making sense of online group structure, narrative and performance using the lens of complex adaptive systems theory. Online support communities are complex, dynamic systems subject to numerous internal and external factors. How internal factors (e.g. interactions between individuals in conversation-driven online health groups) interact with external factors (e.g. technology design, demographics), leading to different performance levels (e.g. support matching, information quality).

Panel: Nikol Rummel (Theories), NN (Methods), Karsten Stegmann (Support)

Revisiting Learning Communities:
Innovations in Theory and Practice

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Abstract: The purpose of this workshop is to advance conceptions of learning communities by considering exciting new lines of research on them. While learning communities such as Brown and Campione's Communities of Learners (CoL, 1994) and Scardamalia and Bereiter's Knowledge Building Communities (KBCs, 1994) are foundational ideas in the learning sciences, the field has come a long way since with innovations in learning communities across a range of contexts. To do this, this workshop will bring together participants interested in the theory and practice of learning communities as we together consider various examples of cutting-edge learning community research.

Introduction

Learning Communities are a central tenet of the Learning Sciences. Despite the immense contributions of well-known learning communities, like Brown and Campione's Communities of Learners (CoL, 1994), Scardamalia and Bereiter's Knowledge Building Communities (KBCs, 1994), and Rogoff's OC (2001), new learning communities have emerged in recent years that have yet to be researched together to advance scholarship on them. Now, over two decades since the introduction of learning communities, we believe the time is ripe to refresh old syntheses (e.g., Bielaczyc & Collins, 1999) and capture the exciting innovations in theory and practice that have come about within various educational settings like schools (e.g., Herrenkohl & Mertl, 2010; Hogan & Corey, 2001; Lehrer, Schauble, & Lucas, 2008; Zhang, Hong, Scardamalia, & Morley, 2011), universities (Fischer, Rohde, & Wulf, 2007; Hod & Ben-Zvi, 2014), informal settings (e.g., www.computerclubhouse.org) and more recently online (e.g., Kafai & Fields, 2013; Resnick et al., 2009).

To address the issue of synthesizing the innovative and emerging learning community frameworks with the existing knowledge on learning communities, we have co-founded the Collaboration of International Researchers on Learning Communities (CIRCLES). CIRCLES is already on its way towards growing as an international body of researchers, with membership that has reached over 30 scholars. The group met for the first time at a pre-conference workshop in 2014 at the International Conference of the Learning Sciences (ICLS) and again at a meeting at the 2015 at the International Conference on Computer Supported Collaborative Learning (CSCL). While the group itself is still young, already several exciting initiatives have emerged, such as a closing plenum at the largest Israeli Educational Technologies conference (Chais 2016) (1, 2), a symposium at this conference on Future Learning Spaces for Learning Communities, and a growing website that provides resources for learning community researchers.

Taking the next step forward in synthesizing and advancing CIRCLES-related research, we are in the process of putting together a special issue in Instructional Science that examines innovations in the theory and practice of learning communities. By the time of the ICLS 2016 conference, we will have 12 candidate articles nearing their full submission deadline. We hope to use the pre-conference workshop to help them make final refinements and so that we can rise above the individual pieces and integrate them into a collective story about innovations in learning communities. At the same time, this meeting will contribute to the learning sciences community by having its members think together, share ideas, and contribute their own perspectives on a set of innovative lines of inquiry. Thus, this pre-conference workshop serves a dual purpose of advancing the special issue contributors' research and advancing learning sciences scholarship.

Specifically, this workshop will address theoretical, methodological, and design innovations in learning communities. By bringing together cutting edge learning community research, we will address questions such as:

- Theories of learning communities: What are learning communities? What are the different ways they are conceived?

- Participant learning: How do participants' practices shift within learning communities? What are the different ways people collaborate within learning communities?

- Community level transformations: How are learning communities formed and how do they develop? What happens when multiple learning communities interact?

- Design: What principles should guide the design of certain types of learning communities (e.g., online communities, multiple or overlapping communities, epistemic communities)? How does technology support certain learning community practices?

This workshop addresses the conference theme of "Transforming Learning, Empowering Learners" by focusing upon a central idea of learning sciences research that re-conceptualizes educational spaces, activities, and discourse. At the core of learning communities is the idea that students do not just learn about and to do something, but they learn to become active and contributing members of a particular community. By framing this workshop as part of a long-term learning endeavor that is structured as a learning community, our participants "gaze back to the commitment of the learning sciences to provide a more insightful understanding of how people learn" (3).

Workshop agenda

The workshop has been organized into four sections. Before the conference workshop, contributors have been asked to write abstracts of their posters, which will be distributed and commented upon by all the other participants.

Section 1 - Who are we?

The group will engage in an ice-breaking and experience sharing activities to (a) explore where have we left off and the progress made over the past year; (b) build group cohesion; and (c) make sure that new members are given a legitimate place in the group.

Section 2 - What are we building upon?

The group will engage in a structured posters session focusing upon the innovative learning community research (predominantly from the special issue candidates). At first, each of the candidates will give three minute "appetizers" about their poster. Then, several rounds of interactive discussions will occur around posters so that everyone participating in the workshop will have a chance to engage with all of them. The purposes of these activities are to (a) give all the participants a chance to get to know each poster and discuss issues with the authors; (b) give the contributors feedback on their posters.

Section 3 - What differences and similarities do we see between the posters?

The group will engage in structured small group discussions around sets of related posters. An interacting group format will be designed such that groups major in one set of posters but also have opportunities to interact with other group members to facilitate cross-group knowledge sharing. The purpose of this activity is to identify central ideas related to the different posters to synthesize the different research projects.

Section 4 - What have we learned and where do we go from here?

The group will engage in a whole group discussion as well as closing activity to (a) reflect on what we learned, both individually and collectively, and (b) to plan future activities.

Expected contributions

We envision this workshop as a vital next step in the development and sustenance of our ongoing international research community, CIRCLES. As an outcome of this workshop, we will advance ideas related to the workshop theme on innovations in learning communities. Additionally, this will be a great opportunity to cross-fertilize ideas between the 12 special issue contributors as well as the other participants' research. We will continue to use our CIRCLES collaborative internet platform (4) to pool resources from different disciplines, connect research and practice in various domains, examine current and future challenges, and contribute to a solid research foundation that can significantly advance the field.

Endnotes

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Acknowledgments

'Jugaad': Transgressions Within Research Methodologies

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Abstract: Research as an organized scholarly activity is a powerful tool that can inform policy and governance. Policy and programing in most countries is supported by research and although not always visible, that research plays an important role in how socio-political systems are viewed and shaped in countries across the globe. Therefore conducting research with a lens that aligns with the local ways of knowing and thinking is critical. When the methods and methodologies align with the ways research is conducted then the inferences that are drawn will have greater benefit for those most greatly affected, the locals. The current research paradigms within learning sciences tend to be grounded in methodologies that developed out of 19th and 20th century educational and social sciences that emerged in the West. This paper examines the need and utility to develop and design research methodologies that aligned with the local ways of knowing and thinking.

Keywords: Research methodologies, design for social justice, design for equity and empowerment

"Jugaad (pronounced as ju gaad) is a Hindi word that means, an innovative fix, an improvised solution born form ingenuity and cleverness. Also know as 'zizhu chuangxin in China, 'gambiarra' in Brazil and 'jua kali' in Kenya (Radjou, Prabhu & Ahuja, 2012).

Introduction

Despite current research that demonstrates people's ways of knowing and thinking are shaped by their culture and context (Bang & Medin, 2010; Banks, 2007; Gutiérrez, 2012; Nasir, 2002) most research methodologies used to understand how people in the majority world learn, create and apply knowledge continue to be grounded in western epistemologies (Chilisa, 2011; Kovach, 2009; Wilson, 2008). The majority world is a term that is used to denote places where most of the human population resides, instead of the inaccurate descriptions such as developing or third world countries. It can also be used to refer to people and places that were historically colonized. Given that there is a need to focus on local ways of knowing and thinking while conducting research within communities of the majority world and other marginalized communities, this paper examines the process associated with developing and designing research methodology that is aligned with local ways of knowing and thinking.

Research as an organized scholarly activity is a powerful tool that is used for designing policy for governance (Bishop, 1998; Minh-ha, 1989; Pidgeon & Cox, 2002). As Kovach (2009) explains " Policy and programming grow out of research, and while the influence of research and its methodologies is not always visible in the policy cycle, research is where it starts." Thus the act of conducting research with a lens that aligns with local ways of knowing and thinking allows for inferences that are drawn to have a greater benefit for the local community (Wilson, 2008). In an interview on the radio program *This American Life* (Episode 444, 2011), Susan Watkins describes how research methods such as semi-structured interviews and surveys could not capture the exchange of information about AIDs that occurred in informal social interactions among the rural Malawians. Watkins explained that in order to effectively understand the experience and impact of AIDs infected people in the community it was necessary to understand "what people said to each other, rather than to interviewers, about AIDS or their strategies for avoiding infection and death." Watkins realized that research grounded in current prevailing methodologies did not have the capacity to uncover and deeply understand how rural Malawians communicated with one another about AIDs. Local Malawians ways of knowing and thinking about AIDs was strongly attached to their epistemology (meaning making through private informal conversations). In response to this disconnect, Watkins designed a methodology that she called *Heresay Ethnography*. Watkins and Swidler (2009) write in their paper titled *Heresay Ethnography: conversational journals as a method for studying culture in action,* about "how cultural insiders kept journals about who-said-what-to-whom in conversations they overhear or events they participate in during the course of their daily lives"

(p. 162). Malawians created knowledge about AIDs through informal social interactions and by aligning her research methodology and methods with the local ways of generating knowledge, Watkins was better able to understand how AIDs information is communicated in the Malawian community. The above example provides a profound observation that enabled Watkins to create an innovative "fix" (Jugaad), thus transforming her research methodologies in a way that respected the local (majority community), thus maximizing the benefit to the Malawian communities.

Challenges and strategies for how to develop methodologies aligned with local ways of knowing and thinking

Designing research approaches that align with local ways of knowing and thinking is not an easy task. Lupele et, al. (2015) highlight this concern, " As novice researchers, we are confronted with the challenge of generating new research approaches (or working with existing ones) that help us contribute to research as a process of social transformation in our own societies" (p.46). Additionally, once an innovative research approach is designed and implemented, it is often met with concerns of legitimacy (reliability and validity) from other researchers whose approaches are grounded in the dominant western research paradigm (Russell & Hart, 2003). The lack of written documentation in cultures whose traditions are grounded in oral ways of knowledge creation further complicates the issue of what counts as knowledge and what counts as beliefs/local opinions. This is particularly compelling since research that is acknowledged today tend to draw on the distinction between the "objective" data gathering as fact based knowledge, versus "subjective" data such as beliefs/local opinions. Within the dominant research methodologies, knowledge is supported by factual information, while beliefs/local opinions consists of non-factual information (Latour & Woolgar, 1979).

When research data gathering is dichotomized into what is understood as knowledge versus beliefs/local opinions, researchers trained in western research approaches have considered beliefs/local opinions as unreliable information. For example, in 2008 Prof Blair Hedges, a herpetologist at Penn State University in the United States reported that he discovered the smallest snake in the world (National Geographic News, 2008). While he discovered the snake in Barbados and named it 'Leptotyphlops carlae' after his wife Carla (BBC, news 2008), the local community in Barbados questioned the discovery by asking (over internet blogs and radio) "How can someone 'discover' a snake long known to locals, who called it the thread snake." (MSNBC, news 2008). As one of the locals put it simply "…my mother, showed me the snake when I was a child." (MSNBC news, 2008). As the associated press (2008) reported, "Hedges says that he understands Barbadians' angry reactions, but under established scientific practice, the first person to do a full description of a species is said to have discovered it and gives it a scientific name." In this statement, he implies that the intergenerational knowledge transfer (mother to son) is not a valid way of knowing in the scientific world. Also, through this example it is observed that although the western scientist agrees that the end point (knowing the snake) might be the same, the process (ways of knowing) through which he describes the snake is more legitimate than the process through which the local community transfers knowledge about the snake.

The prioritization of one way of knowledge generation over another has created a power dynamic between researchers in the western world and people living in the majority world. Smith (1999) suggests, "research is a part of the colonization process to the extent that it seeks to define so-called legitimate knowledge " (p. 173). This power dynamic has led to a deep distrust and suspicion of research in communities across the majority world (Hughes, 2012). Given the history of colonization across many countries in the majority world and the dominance exerted by western research approaches, it is an uphill task to decouple western research approaches from being applied to contexts within the majority world.

Despite it being difficult to understand and use methodologies that align with local ways of knowing and thinking, it is imperative to conduct research in the majority world that respects, benefits, and is responsible to people living in these parts of the world. There are several different models that point researchers in the direction of conducting research that aligns with local ways of knowing and thinking. However one common theme that emerges from all these models is partnership building. For example, Native American communities in the United States recommend all western researchers that desire to conduct research in their community, refer to the 'bill of ally'. The 'bill of ally' shares ways in which researchers can build partnerships with community members. For example, the *bill's* first tenant states, " Do not act out of guilt, but out of genuine interest of challenging the larger power structure". The bill also emphasizes the need to listen, reflect and be aware of one's own privileges. Overall, the tenants in the bill ask researchers to be allies and build a relationship of equity with the community members. Researcher-community partnerships that reflect equity are not always easy to build, they take time, effort and negotiation. They require researchers to be honest about their agendas and that

the needs of community come before their own agendas. We highlight some examples of how researchers and community members have negotiated mutually beneficial partnerships that reflect equity.

Building partnerships with local communities

Partnership in a South Asian community

Bhutan, a small kingdom in the Himalayas that is geographically wedged between India and China, has through government policy limited the number of western visitors (tourist and researchers) who come to the country for short term visits. The government of Bhutan has designed and implemented this restrictive policy after observing the negative effects of westernization in other parts of the Himalayas. For example Norberg-Hodge (1991) describes how a self-sustaining and ecologically balanced society in Ladakh (a region in the Indian Himalayas) was almost completely destroyed in a short period with the unrestricted influx of western visitors (tourist and researchers/development specialists). Norberg-Hodge (1991) also observed that after restrictions were lifted there was an influx of western visitors, which caused some Ladakhi's to view their own culture as inferior and placed pressure on the people of the region to modernize/westernize. The policy of restricting western visitors to Bhutan has helped preserve cultural identity among the people of Bhutan (Brunet, 2001). Western researchers who come to Bhutan are allowed to conduct research in the country only if they are willing to be in the country for longer periods of time and recruit a local partner who is willing to support their stay in the country. Although there is no minimum stay required, visas requested for researchers who want to visit for less than three months are often rejected by the Bhutan government. Therefore this model of restricting western researchers through government policy has aided in achieving equity among western and Bhutanese research partnerships.

Partnership in a Native American community

For the past several years, the University of Idaho (UI) in the United States and the Coeur d'Alene Tribe have partnered on efforts to provide enriching, culturally-relevant Science, Technology, Engineering, and Mathematics (STEM) education efforts for Tribal youth. In 2009, at the request of the Coeur d'Alene Tribe's Department of Education, UI faculty in the College of Education (CoE) began pursuing National Science Foundation (NSF) funding to support the exploration of effective and engaging STEM enrichment in a non-formal educational setting. A successful grant proposal launched the 2012-2015 "Back to the Earth" STEM education program that partnered with two neighboring tribes, the Coeur d'Alene and the Spokane Tribe of Indians. Programming attempted to merge Western watershed science with "Traditional Ecological Knowledge." However, in the project's initial year, the UI project team immediately encountered tensions with the Tribal communities. Tribal community members and staff were frustrated by the seeming lack of understanding of the history and sovereignty of the community and the sense of "expertise" that was displayed by the UI team and researchers. This lack of respect and relationship with Tribal members threatened to derail the project. However, through attention to the development of relationship, and a desire to develop a reciprocal partnership, the project was able to move forward towards collaborative development and research that aligned with both the University teams and community goals to develop a truly engaged and culturally rich STEM experience for community youth.

Partnerships for research and learning in southern Africa

In the southern African environmental education research community a tradition of research that is generative and partnership oriented is emerging amongst researchers and community partners. This research approach is dialogic, formative and learning-centered (where researchers are also learners in community, along with those that they participate with). Local 'indigenous' researchers, familiar with the research contexts and local cultures of people, seek to work *with* their own, and other communities to unfold research questions of interest and value to communities, and to develop approaches to engaged, generative research which supports an expansive social learning orientation (Kachilonda, 2014; Masara, 2011; Mukute, 2010, 2015; Pesanayi, 2016). One recent example is the research of Pesanayi (2016) in which he and a small team of researchers are working within a learning network structure consisting of the local agricultural college, local economic development officers in the municipality, local women subsistence and communal farmers, local NGOs and other community members to collectively engage with the question of how to bring water to food gardens. The unfolding research responses emerged from collective review of three generations of activity; the first where indigenous water harvesting practices (termed *Galesha* in the local isiXhosa language) were used and marginalized; these practices were later replaced by pipe and pump approaches to water provisioning. When this approach failed due

to inadequate technical knowledge and support; communities sought new solutions. Building on and expanding historically used indigenous knowledge of *Galesha*, and bringing this together with new knowledge produced by the Water Research Commission on modern rainwater harvesting practices and approaches in the research and learning network, members of the learning network were able to deliberate and decide on those practices that were most suited to, and possible to work with, in response to their research question. This research partnership system is interesting because it enabled boundary crossing between the college, municipality and the community (who were previously working in silo's). This boundary crossing process introduced curriculum change into the college that now takes better account of community and farmers' knowledge and concerns. Stronger learning-centered relations have been established between farmers, college lecturers, and local municipalities. Most importantly local women farmers in the area were better prepared for the recent drought and are more able to ensure household food security.

Conclusions and implications for the Learning Sciences

As we have demonstrated above partnership building is the corner stone of working with communities of the majority world. Researchers in the learning sciences are already moving towards the direction of - how to conduct research that is equitable to all people involved in the research process. The design based implementation research group (DBIR) has provided some initial guidance on how to bring the dialogue about research – practice partnership into the mainstream research approaches (Coburn, Penuel & Geil, 2013). DBIR itself builds on progressive research traditions in the learning sciences such as design based research (DBR) approaches that encompass the process rather than the output.

We believe that the learning sciences community is poised to make a difference. Research approaches such as community-based participatory research (CBPR) that stem from "participatory research" where the core philosophy is of inclusivity can be given validity within the research community. CBPR shifts the concept of "research from one in which the community is a "laboratory" for investigation to one in which community members not only participate in the inquiry process but also contribute their own knowledge" (Hacker, 2013, p. 5). As mentioned above in the case example from southern Africa, research methodology processes are emerging to probe and develop the potential of expansive learning research as a generative approach to community oriented research. Such an approach to research is situated in culture and history, while also being committed to an open process of knowledge co-generation and learning. All in the research process are learners, and collectively the researchers and research participants produce new knowledge and/or solutions to concerns around a shared object or concern. Finally, there is also a large body of work emerging which seeks to articulate the processes and meaning/s of Indigenous research methodologies (e.g. Smith, 1999; Kovach, 2009; Michell, 2009; Wilson, 2008; Tuck & McKenzie, 2015; Lupele et al. 2005). Such research practices that places primacy and respect on the community can embolden researchers from outside and within the community toward research that places a priority on respect, relationship, reciprocity, and responsibility.

We hope that this paper sparks a dialogue within the learning sciences research community to conduct research that is beneficial and responsible to the people who are engaged in research within the majority and more marginalized populations.

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Acknowledgments

Organizing Design-Based Implementation Research in Research-Practice Partnerships: A Workshop

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Abstract: This workshop focused on organizing equitable design processes and promoting the agency of educators at different levels of systems in conducting design research inside a research-practice partnership. Members of research groups from three different regions of North America and Europe offered cross-national perspectives on designing with educational organizations and will engage participants directly in curating resources teams can use to organize research and development efforts in partnerships.

Rationale for the workshop

The learning sciences have long embraced collaborative design as a feature of design research (Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Druin et al., 1999; Roschelle et al., 1999; Voogt et al., 2015). Collaborative design within research-practice partnerships presents both expanded possibilities and new challenges. Research-practice partnerships are long-term collaborations between practitioners and researchers that are organized to investigate problems of practice and solutions for improving the outcomes of educational systems (Coburn, Penuel, & Geil, 2013). On the one hand, they have the potential for broader impacts, because designs aim to impact practice in larger systems and networks (Cobb, Jackson, Smith, Sorum, & Henrick, 2013). In addition, they have potential to develop important "context theories" related to learning (Edelson, 2002), focused specifically on the conditions for broad and equitable implementation of innovations. At the same time, such partnerships demand more up-front negotiation of the problems that will become the focus of collaborative design (Penuel, Coburn, & Gallagher, 2013). In addition, they require organizing partnerships to address concerns across multiple levels of systems and settings where differences of power and inequity deserve attention (Bang, Medin, Washinawatok, & Chapman, 2010).

Workshop goals

There were three major goals pursued in the workshop, as described below.

Workshop Goal 1: To provide participants with heuristics and models for how to organize collaborative design within research-practice partnerships

A broad range of theoretical perspectives is necessary to inform collaborative design in partnerships. The workshop organizers draw on theories of curricular design (Ben-Peretz, 1990; van den Akker, 1999), social practice theory (Dreier, 2009), and cultural-historical activity theory (Engeström, 1987; Engeström & Sannino, 2010) to inform the design of learning environments. In addition, the group draws on theories of organization and leadership (e.g., Hopkins, Spillane, Jakopovic, & Heaton, 2013) to inform work to design supports for implementation and theories of participatory design (e.g., Ehn, Nilsson, & Topgaard, 2014) to structure collaborative design.

Workshop Goal 2: To share, in the context of the workshop, how these theories inform design decisions in our research, illustrating their potential value for building knowledge and developing theory in the learning sciences

Collaborative design has strong connections to the conference theme. In order to "re-design learning environments to bring about deep learning," partnerships with educators are crucial. Teachers, informal educators, and leaders of educational organizations each inhabit places and hold keys to changing these environments. In addition, the research methods we will highlight will help us "better assess the extent to which educational institutions have shifted towards deep learning in their pedagogical approaches." The workshop will offer practical methods for assessing implementation and effects on students that partnerships can use.

Workshop Goal 3: To provide a context for articulating what is new about these new forms of design research and also to contribute to the evolution of design research as a signature approach within the learning sciences

Because a commitment to collaborative design has been part of design research since its inception, it is important to characterize what is unique about design within long-term partnerships with educators. The workshop will therefore highlight the implications of shifting to design across levels of a system and across multiple settings and including stakeholders from multiple levels of a system in design.

Workshop structure and agenda

The structure of the workshop was organized around a learning cycle that mirrors a cycle of joint work within a research-practice partnership. It began by surfacing the ideas and perspectives of participants and leaders about the challenges and opportunities inherent in conducting collaborative design research in partnerships. Program leaders shared resources they use to address challenges and opportunities in partnerships in two different formats, whole group panel discussions and small-group mini-roundtable discussions. We then invited workshop participants to raise new questions and identify new or refined needs for engaging in partnership work. The concluding part of the workshop provided opportunities for leaders to disperse to small groups to initiate a resource curation activity that leaders from the Research+Practice Collaboratory (http://researchandpractice.org), a clearinghouse for resources related to partnerships, will continue after the workshop.

Table 1: Agenda for the workshop

Time	Activity	Description and Rationale
9:00	Introduction and Initial Ideas	Participants and leaders introduced themselves, their reasons for participating in the workshop, and their ideas about the challenges and opportunities inherent in DBIR within partnerships. Workshop leaders led a discussion to surface themes, differences, and contradictions among perspectives voiced.
10:15	Panel Discussion	Penuel led a panel discussion among the leaders related to several key themes that are common to our work: identifying a focus of joint work or the "germ cell" (Engestrom & Greeno, 2015) to guide work; the challenges of working across levels of a system; the roles of partners; addressing turnover and induction of new members; the need for rapid feedback; and integration of higher education institutions. The panel also addressed tensions and contradictions identified in the introductory session.
11:00	Break	
11:15	Presentation	Bell led a brief presentation on the different lines of work in partnerships.

Table 1: Agenda for the workshop (concluded).

Time	Activity	Description and Rationale
11:30	Participant-Driven Discussion	During this part of the workshop, we invited participants to share their experiences of partnerships and pose new questions and challenges related to partnerships that have arisen from the morning panel and discussion. We recorded these ideas and return to them to help organize afternoon sessions.
12:00	Lunch	
1:00	Rapid Roundtable Discussion	What we called a "rapid roundtable" discussion provided an opportunity for participants to rotate through different "stations" led by workshop presenters about key tools and resources they find useful to their work. All participants had a chance to rotate through all five stations.
2:00	Presentation	Leaders gave a brief presentation of 1-2 theoretical perspectives they find uniquely relevant to work in research-practice partnerships.
2:15	Break	
2:30	Resource Curation Activity	McKenney led an activity in which she (1) synthesized different challenges identified, with input from the group, (2) helped the group organize into smaller groups to focus on specific challenges, (3) facilitated small groups in identifying and beginning to assemble (links to) resources that could help partnerships address these challenges, and (4) led a brief report out to conclude the workshop. Subsequent to the workshop, Bell and Penuel, PIs for the R+P Collaboratory, took over curation of these resources on the Collaboratory website.

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Acknowledgments

Situating Multimodal Learning Analytics

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Abstract: The digital age has introduced a host of new challenges and opportunities for the learning sciences community. These challenges and opportunities are particularly abundant in multimodal learning analytics (MMLA), a research methodology that aims to extend work from Educational Data Mining (EDM) and Learning Analytics (LA) to multimodal learning environments by treating multimodal data. Recognizing the short-term opportunities and long-term challenges will help develop proof cases and identify grand challenges that will help propel the field forward. To support the field's growth, we use this paper to describe several ways that MMLA can potentially advance learning sciences research and touch upon key challenges that researchers who utilize MMLA have encountered over the past few years.

Introduction

Multimodal learning analytics (MMLA) (Blikstein & Worsley, in press.; Blikstein, 2013; Worsley, 2012) sits at the intersection of three ideas: multimodal teaching and learning, multimodal data, and computer-supported analysis. At its essence, MMLA utilizes and triangulates among non-traditional as well as traditional forms of data in order to characterize or model student learning in complex learning environments. However, as we describe later, the ways that researchers utilize multimodal data vary widely.

A key tenet of MMLA is the recognition that teaching and learning are enacted through multiple modalities. Even in a traditional classroom, teachers engage in significant multimodal behaviors (voice inflections, gestures, etc.) in order to emphasize and de-emphasize different ideas in a lecture. Similarly, students draw upon a host of modalities in order to demonstrate their knowledge, and, more importantly, to gain in their understanding of a given subject area. In this way, MMLA draws upon certain ideas from Constructionism (Papert, 1980), namely the importance of conceptualizing and constructing using a broad set of modalities, and Embodied Cognition (Kirsh, 2011), the ability for embodied experiences to spur cognition.

However, the ability to tractably study multimodal teaching and learning is largely limited by how well we can perceive, qualify, and quantify multimodal data. Multimodal data includes anything from gestures, to speech, to emotions, to data about social interactions. (Note: For more detailed examples of multimodal data used in MMLA see Blikstein & Worsley (in press), Blikstein (2013) or Worsley (2012)). In years past, analyzing multimodal teaching and learning was completed using human inference and coding. Human observation and analysis provide the innate ability to situate, contextualize and interpret the multimodal data that is emerging from a given learning scenario. MMLA aims to maintain the richness and highly contextualized nature of traditional human-mediated qualitative analysis but with the added benefits of: (1) quantifying those data in news ways: and (2) leveraging innovative sensors to capture data that is not easily perceivable through human observation (e.g., galvanic skin response, eye gaze). To this end, recent developments in non-invasive multimodal sensors have made the process of capturing rich qualitative process data more tractable.

Finally, MMLA is heavily influenced by emerging capabilities in Big Data and computational analysis. For example, the resurgence of machine learning and artificial intelligence provides new ways for analyzing the wealth of multimodal data that can be collected through low-cost, non-invasive sensors. However, as we will describe in the next section, the affordances of computer-supported analysis are not merely in the form of black-box predictions. Instead, computer-supported analysis can mean anything from normalizing the data, to making it easier to interpret by human inference, to a fully automated system that provides real-time help or feedback.

Applications of multimodal learning analytics

The different ways for using MMLA that we describe below are not exhaustive nor are they limited to multimodal analysis. Instead, we attempt to provide a glimpse of some various ways that researchers are using MMLA so as to suggest how MMLA, and learning analytics writ large, could be used more broadly.

Visualizing/Representing information for human inference

While many would assume that MMLA necessarily eliminates the need for human inference, this is absolutely not the case. As the reader will note from this sub-section and others, human inference and judgment play a very important role in MMLA. For example, MMLA could be used to support more traditional qualitative analysis by presenting the researcher with normalized bio-physiology data to interpret alongside the audio transcripts and raw video footage. In particular, if a researcher were utilizing electro-dermal activation data, it would be beneficial to transform those data so as to account for individual differences in stress response and allow the researcher to visualize those data in a synchronous fashion with the other data streams. The researcher could then go about interpreting each participant's experience using data that would otherwise be unknown to an observer. Similarly, teachers and students could use synchronized views across modalities to better interpret learner and instructor experiences. One example of software that has specifically been developed for the purpose of supporting improved visualization of multimodal data is Chronoviz (Fouse, 2011).

Prediction of indicators

A very common strategy within computational analysis is to acquire a data set, code that data for something in particular (e.g., emotions from videos: happy, sad, angry, confused, surprised, etc.), and then utilize those hand-coded data to automatically code a future dataset. The ability to automatically make a prediction about someone's perceived emotional state, for example, can then become a piece of information used by a qualitative researcher, the focal point of a computational analysis, or used to control a data-driven application (described in the next section). Worsley & Blikstein (2015) is an example of work that uses predictions of indicators. Specifically, they used automatically derived facial expressions to compare the frequency that students seemed to express confusion in a dyadic hands-on learning activity.

Data-driven interventions

In the era of data-driven applications, one cannot help but consider the potential for using behavior-level predictions to determine an appropriate form of intervention or feedback that a learner should receive. For example, a system could analyze the combination of speech, video, and text-based responses that a student provides in order to determine if the student has achieved proficiency with a given skill. Based on that calculation of proficiency, the system could then recommend a future set of activities for the student to complete, much in line with existing intelligent tutoring systems.

Constructing models of interaction

Instead of automating feedback, a common objective with MMLA is to model learner experiences. Modeling can inform the design of a given space or improve one's understanding of a given theory or conjecture. In such cases, indicator predictions can be utilized within a Hidden Markov Model (HMM), for example, to model the ways that students transition from one behavior to the next. For example, recent work by Tissenbaum, Kumar, and Berland (under review) developed an HMM of learner productivity while participating in a multi-touch, tabletop experience. In this work, they also created a Markov Model to provide insight into the types of challenges learners face when participating with tabletop applications.

Evaluating conjecture-based learning designs

As briefly suggested in the previous section, a particular opportunity that comes about through MMLA is the ability to study, with an enhanced level of complexity, multimodal embodied learning experiences. Rather than rely merely on the measurement of pre- to post-test learning gains, or on human coding, MMLA can provide a means for an increasingly detailed analysis. One example of this is recent work by Abrahamson, Shayan, Bakker, and Van der Schaaf (in press), in which the convergence of action logging, eye-tracking, and video analysis created a means for deconstructing learner experiences with a sufficiently high level of specificity that the authors were able to confirm their conjecture of students creating, seeing, and manipulating "attentional anchors," imaginary objects that the students were visualizing on a computer screen.

The above paradigms range from being purely in support of a qualitative analysis to fully automated analyses. Hence, the purpose of MMLA is not to prescribe a certain set of research questions but, instead, to support effective responding to the diversity of research questions examined through the learning science.

Connecting learning with multimodal data

One prerequisite for using MMLA is having multimodal data. However, going from data to results will typically require the use of new analytic tools and techniques. To help elucidate this process, we use the following paragraphs to provide a short overview of how we conceptualize the relationship between learning-related constructs and the multimodal data that we capture and analyze.

Learning constructs

As education researchers, our primary objective is to conduct analyses that ultimately contribute to the field's understanding of teaching and learning. In particular, we are often looking to make a conjecture about some learning-related skill, attribute or construct. For example, in a given study we may wish to study student conceptual change, or student identity. For the purposes of this paper, we will refer to these skills, attributes or constructs as "learning constructs."

Indicators

Similar to any analysis, in order to ascertain the development of a given "learning construct" we will look for one or more indicators. For example, in the case of documenting conceptual change, one indicator could be a change in the explanation that a student provides for a given phenomenon. This could be language-based (i.e., in the words and justification that the student provides) or pictorial (i.e., demonstrated through comparing two drawings that the student made of the phenomenon, one before an intervention and another after the intervention). The point here is simply that for a given "learning construct" there can be any number of potential indicators that we use to prove or disprove a given "learning construct." These indicators are not synonymous with the learning construct, but tend to help us in making inferences related to the construct in question. In the same way that we have indicators in traditional education research, we also have indicators in MMLA. These indicators could be system-generated predictions from text, audio, stress levels, emotions, or any number of other data streams.

Analytic techniques, tools, and data

Indicators are typically generated by one or more analytic techniques, as made available through a given analytic tool and one or more forms of data. Hence, what MMLA is providing is not necessarily a completely new approach for conducting research as much as it is enabling researchers to tap into a new, or complementary, set of indicators, as derived through computational analyses of multimodal data.
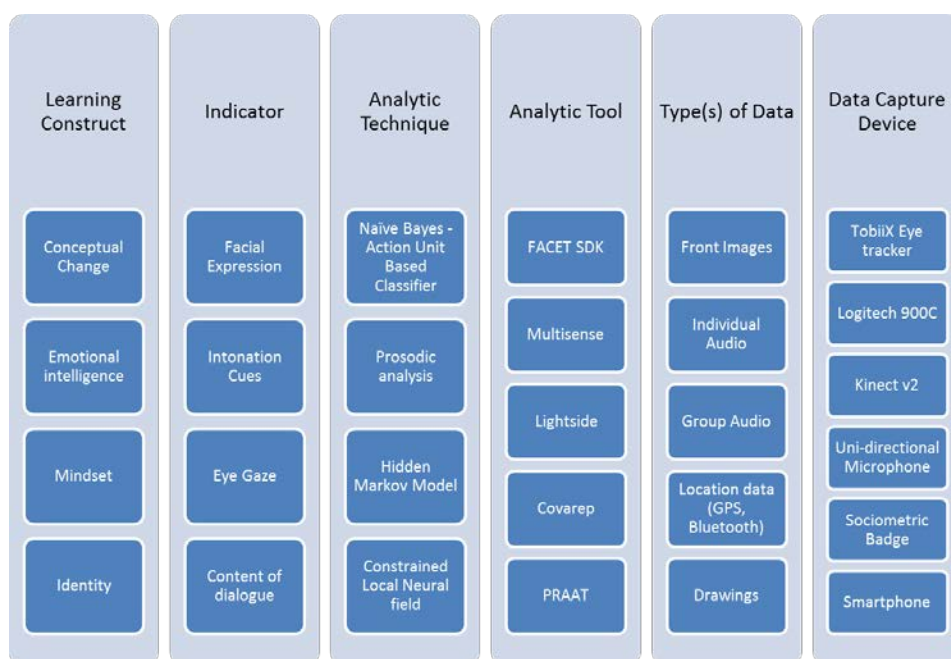
Figure 1. Sample Landscape of Constructs, Indicators, Techniques, Tools, Data Types and Data Capture Tools.

Figure 1 provides a simple representation of the relationship between learning constructs, indicators, analytic techniques, analytic tools, data, and data-capture devices. Identifying the appropriate mapping from "learning construct" to data and data capture tool is an important consideration, as each decision point can impact the resultant analysis. Similarly, recognizing that a single construct can comprise several indicators, and that a given indicator can involve multiple analytic techniques and/or multiple types of data, adds to the complexity of MMLA. Some of the other challenges that have been raised by the MMLA community are related to questions of data privacy, cost, data synchronization, and how to keep the data capture process sufficiently naturalistic.

Examples of emerging research

Even with the aforementioned challenges, a number of researchers have begun to identify important findings from MMLA-related studies. For example, Schneider et al. (in press) conducted innovative research that includes the use of mobile eye-trackers and audio data with dyads using a tangible user interface. In their study they compared low and high-performing dyads, and were able to draw important insights about how to automatically analyze collaboration quality using MMLA techniques. Grover et al. (in press) are conducting a similar line of research around collaborative problem solving in K-12 by combining clickstream, gaze and gesture with measures of proximity, engagement, and turn-taking during pair programming. Through this work, they are modeling the practices associated with high performance collaborations, paying particular attention to the constituents of high collaboration interactions.

Conclusion

There is a host of ways for utilizing MMLA to advance the learning sciences. In recent years researchers have used MMLA to model student performance, predict student learning, and construct models of student–student/student–artifact interactions (Grafsgaard, 2014; Schneider & Blikstein, in press; Worsley & Blikstein, 2015a). Utilizing these techniques enables researchers to study complex learning environments through a different set of lenses that could serve as a strong complement to existing work in the learning sciences.

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How Students Learn in East Asian Cultures and How That Learning May Evolve in the Future

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Abstract: This workshop focuses on how East Asian cultures furnish unique contexts for education and learning in the region. We share and discuss ongoing research, observations, and theory buildings with regard to the interdisciplinary research on the learning sciences, with the unique context of the interplay of sociocultural, language, and political and historical factors in East Asia. The guiding question is: How learning experiences are shaped by the cultural contexts? In elaborating the uniqueness of the Eastern Asian cultural context, existing studies show that the cultural beliefs, the native languages and bilingual contexts, virtual adolescent social lives, have impacts on the teaching and learning. These studies and the observations of those impacts initiate the introduction to the general theoretical synthesis of Interest-Driven Creator (IDC) theory.

This half day workshop aims at reaching a consensus on the benefits of exploring wisdom from East Asian cultures in transforming learning towards the cultivation of interest-driven creativity. Our knowledge synthesis effort will entail a) a consolidation of relevant research findings to date; b) a negotiation of understanding on the East Asian cultural factors by invoking the broader perspectives of researchers from other cultural contexts; and c) new research questions, methodologies and theoretical inputs to inform forthcoming studies and practices on the topic. In particular, we aim at developing a conceptual paper beyond the workshop to be submitted to a suitable journal, with the aim of triggering more cross-cultural dialogues among international scholars on the captioned topic.

Keywords: East Asian cultures, interdisciplinary studies, sociocultural lens, research and practice

Organizers' background

The organizers represent learning scientists from culturally unique contexts in Eastern Asia, including Mainland China, Singapore, Hong Kong, Japan, South Korea and Taiwan, as well as expertise from the Western academic community. All of us are experienced in research from multi-disciplines with the cultural factors as a highlighted concern.

Introduction

Learning and teaching are culturally dependent. Much sociocultural research shows that cultural factors are related to motivation and cognitive process (Millar et al., 2013; Han, 2010) and thinking styles (Lun, Fischer, & Ward, 2010). Likewise, Eastern culture has produced unique contexts for shaping learning and teaching: contexts which are very diverse, as manifested in the learning activities, thinking styles, class traditions, teacher development as well as in the outcome results of learning assessments (OECD, 2010). Different language structures can also play a role in orchestrating the learning experience.

This workshop brings together learning scientists from East Asian culture contexts to share research findings from culturally unique contexts in this region, with the specific objectives of a) to present research on the specificity of students learning in East Asian sociocultural contexts; b) to examine how sociocultural factors have shaped the education systems and practices in the region, discussing which factors may inform 21st century learning ; and c) to explicate the Interest-Driven Creators (IDC) theory and bring forward cross-cultural dialogue around the interplay of sociocultural, semiotic and individual factors.

Themes

Cultural uniqueness must be highlighted in the multi-disciplinary investigations of learning sciences. Thus in this workshop, preliminary findings obtained in the research teams will share their undergoing research projects,

with the uniqueness of East Asian cultural factors as one of the highlighted points.

The direction of cultural influences, along with consideration of future evolution, has been developed in a sociocultural lens into the main themes of workshop, in particular: (1) how students learn; (2) how cultures, values and biases have shaped education in East Asia and; (3) theoretical frameworks to guide the transformation of East Asian education.

How students learn in East Asian sociocultural context. We shall solicit contributions on the theoretical foundations of the learning sciences, particularly from the perspectives of of cognitive psychology, neurophysiological and big-data, among others. The invited presentations are pertaining to ongoing studies conducted in the East Asian context, including (but not restricted to): (1) the distinct performance of students in mathematics and native language learning, addressing the impact of the inter-operability of culture, language, and creativity thinking; (2) early childhood brain development and approaches to learning, addressing the impact of exposure to native languages, bilingual contexts, and the interplay of these; (3) the development of core competence and creativity of children in relation to native language, the interplay of culture, language, cognitive mechanisms and neural mechanisms; (4) the uniqueness of learning, given the impact of learning culture, peer pressure, and virtual adolescent social lives.

How have sociocultural factors shaped education in East Asian regions and what kinds of learning interventions are appropriate in positively transforming education in the East Asian context, and what are the challenges? What are the enabling traditional, cultural beliefs (e.g., the Confucian teaching) that we should leverage to design effective interventions? What are the hindering traditional beliefs that we could adapt or change for the better? Intervention includes policy imperatives (e.g. the pervasiveness of examinations).

The theoretical framework IDC. The stress on academic outcomes across East Asia has resulted in severe drawbacks: many students do not enjoy learning; it is difficult for students to develop 21st century competencies. To address this issue, a group of scholars from East Asia and Southeast Asia has launched the Interest-Driven Creator (IDC) Initiative as a theoretical synthesis (Looi et al., 2015). The intention is to co-construct a holistic developmental framework in which students foster their learning interests, capabilities in creation, and learning habits.

Workshop format (half day)

The workshop comprises three stages. Stage one features presentations on various learning sciences studies and their findings within salient East Asian cultures. In stage two, group discussions on the presentations ensue with the aim of understanding, contrasting and rising above local cultural factors by invoking the broader perspectives of researchers from other cultural contexts. The third stage is to seek consensus on what we have known about the East Asian system, what we need to discover and research further, and what the East Asian systems can learn from the rest of the world, and vice versa.

Stage One: Presentations

Invited presentations

(1) Learning sciences studies in East China Normal University: The research team under a five-year interdisciplinary research program of the stated university will present their studies with a focus on deep learning. Special emphasis will be placed on the uniqueness of cognitive, language, executive function development, and the learning paths/strategies of students located in the Chinese sociocultural context.

(2) Studies in East Asian countries/regions from sociocultural perspectives: For instance, researchers along with educational policy makers from Japan will reflect on the Japanese project of public education reform towards building on cultural capacity from the sociocultural lens.

(3) The macro design theory of IDC: Researchers from East Asia will present a synthesis of their vision of teaching and learning reforms in East Asia to overcome the cultural hindrances.

Papers written by these researchers will be solicited prior to the workshop. At the same time, researchers from the other parts of the world with interests in East Asian education systems may also participate by submitting position papers and make their presentations in this stage.

Stage Two: Group discussions

We will facilitate group discussions pertaining to the presentations. Participants may choose one presentation topic that they are most interested in and then form into groups. During these group discussions, all participants

will have the opportunity to: (1) attribute their perspectives on the cultural factors in learning sciences based on their own cultural contexts, (2) discuss related research findings/plans/methods as well as educational practices, (3) address other questions/concerns that related to the presentation.

Stage Three: Open discussions
In this final stage, an open discussion will be conducted with the aim of seeking synthesizing the views arisen from the group discussions. The discussion topics will include but not be limited to:

(1) What are the salient influential cultural factors in the East Asian context?

(2) What do we learn from other cultures for promoting deep learning and improving the East Asian education system?

(3) What are possible future research directions arisen from the discussions of this workshop?

We will also strive towards developing a conceptual paper beyond the workshop and submit it to a suitable journal, with the aim of triggering more cross-cultural dialogues among international scholars on the captioned topic.

Outcomes, contributions, dissemination
The expected workshop outcomes are a) new understanding on how students learn in East Asian sociocultural context, and how it has been shaped by the sociocultural factors; b) elicitation of wider interest and participation in the IDC initiative within the learning sciences community; and c) a joint conceptual paper to be published, in order to trigger more cross-cultural dialogues among international scholars on this topic.

The organizers and participants are promoting the workshop in various Social Media formats, including Twitter, Facebook (https://www.facebook.com/groups/TMCL2015/), personal contacts and our workshop website https://sites.google.com/site/iclsworkshop/. Resources from the workshop, including accepted abstracts and presentations have been made available online on the website in order to guide further discussion in the community.

Program Committee includes the seven organizers and

- Pierre Dillenbourg, Professor of Learning Technologies in the School of Computer & Communication Sciences, and head of the CHILI Lab of Computer-Human Interaction for Learning & Instruction.

- Hyo-Jeong So, Professor of HDT Lab, Department of Creative IT Engineering at Pohang University of Science and Technology, South Korea.

- Nancy Law, Professor and Founding Director of the Centre for Information Technology in Education (CITE), University of Hong Kong.

- Rachel Lam, Research Scientist of the Learning Sciences Lab., National Institute of Education, Nanyang Technological University, Singapore.

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Embodiment and Designing Learning Environments

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Abstract: There is increasing recognition amongst learning sciences researchers of the critical role that the body plays in thinking and reasoning across contexts and across disciplines. This workshop brings ideas of embodied learning and embodied cognition to the design of instructional environments that engage learners in new ways of moving within, and acting upon, the physical world. Using data and artifacts from participants' research and designs as a starting point, this workshop focuses on strategies for how to effectively leverage embodiment in learning activities in both technology and non-technology environments. Methodologies for studying/assessing the body's role in learning are also addressed.

Workshop motivation and objectives

An emerging paradigm of research in the learning sciences is examining how the perceptions and actions of our bodies affect the development of new ideas and new ways of understanding in complex disciplines such as mathematics and the sciences (Abrahamson & Lindgren, 2014). Learning scientists have examined how physical actions, such as gestures, performed spontaneously by both students and teachers "ground" cognition in the environment, providing opportunities for reflection and elaboration (Alibali & Nathan, 2012). Likewise, new environments are being designed that either create social contexts to facilitate physical enactment of ideas (e.g., Enyedy, Danish, Delacruz, & Kumar, 2012; Johnson-Glenberg, Birchfield, Tolentino & Koziupa, 2014; Moher, 2008; Price, Sakr, & Jewitt, 2015) or they attempt to elicit specific actions that explicate critical mechanisms or highlight important relationships (e.g., Lindgren, 2015; Manches, O'Malley, & Benford, 2010; Lyons, Slattery, Jimenez, Lopez, & Moher, 2012). Efforts to consider embodiment in the design of learning environments and to guide learners through "tacit and cultural ways of perceiving and acting" (Abrahamson, 2014) are gaining traction in the learning sciences, and effective strategies for designing new environments and new technologies that have these considerations "built in" are beginning to emerge (e.g., see the volume on learning technologies and the body by Lee, 2015).

The objective of this workshop is to bring together researchers who have conducted studies and created designs in environments that engage learners in physical ways, but who may still wish to think deeply about the kinds of prompts, artifacts, and opportunities for reflection involved in their interventions. Starting with their existing data and/or designs, the facilitators aim to assist participants in exploring how connections have or could be made between the learning goals of the design and the physical and perceptual acts being elicited from learners. Workshop participants will be prompted to think about how these actions could be designed more intentionally, and to examine opportunities for learners to develop embodied schemas or other embodied resources that could be leveraged for transfer and preparation for future learning.

After connections between embodied actions and understanding have been made explicit, workshop participants will explore how these links can be turned into frames for assessing both learning and the design of the learning environment. In other words, how can workshop participants transform what we know about expert ways of perceiving and acting into new forms of assessment that emphasize practice and perception rather than the ability to produce canned knowledge? The workshop also will examine ways that emerging data analytic techniques can be used to support more embodied approaches to assessment.

The culminating product of the workshop is a synthesis of some general heuristics for approaching new learning environment designs. As workshop participants critique and discuss and encourage the work that is presented, facilitators will document common threads in the conversation and identify some general guidelines for approaching this class of design problems. These guidelines are to be augmented by several "design cases" that come from workshop participants in the culminating small group activity. These cases, which are selected by the participants and nurtured by the facilitators, will make salient key aspects of the design process. A summary document with these items is made public following the workshop. Participants will end by brainstorming ways to continue the conversation and further their collaboration.

The target audience for the workshop is designers and researchers who either have existing work that includes a physical interaction component to their instructional intervention, or they have well-articulated plans to include such a component in upcoming work.

Workshop agenda

The planned activities for the Embodiment and Designing Learning Environments workshop include:

- *Opening remarks and framing by the workshop organizers.* Having reviewed and synthesized workshop proposals by participants, the co-organizers for the workshop will give an overview to the problem of designing learning environments that consider embodiment, pulling out themes and common challenges that the group attempts to address in the workshop.

- *Brief research presentations.* Each participant will give a short description of their research or design by "acting out" some aspect of their work using as few words as possible. The point of this activity is to highlight the embodied aspects of the design and suggest opportunities for intervention or further examination.

- *Whole-group analysis of spontaneous learner actions.* The co-organizers will present video or other data from authentic learning environments (classrooms, museums, etc.)—including video clips elicited from participants—where physical actions (gesture, object manipulation) occur naturally. Prompted by guiding questions, the group discusses ideas for how the physical actions observed affected communication, reasoning, learning, etc. within the interaction, and what opportunities there might be for augmentation in a future iteration of a designed learning environment. This analysis session concludes with a synthesis of potential design strategies for embodied learning.

- *Whole-group analysis of designed learner actions.* The co-organizers will then present video data from designed learning environments (e.g., structured classroom role-play activities, interviews where students are asked to perform particular actions, interactive technologies with specific control mechanisms, etc.). Some of these clips also come from participants. Prompted by guiding questions, the group discusses ideas for how these activities can be studied and evaluated in order to bring about insights related to learning and the connection with bodily activities. The analysis concludes with a synthesis of potential methods/measures for conducting research on designed environments for embodied learning.

- *Small-group designs around a single case.* Participants are then put into groups of 3 and asked to choose one of their member's designs/research topics for elaboration into a more detailed "case" presentation. Participants work in their groups, using the previous lists of design and research strategies, and apply these to their cases. Groups present their final cases in a short multi-modal presentation. The cases are captured in video and text descriptions by the facilitators so that they can be shared as products of the workshop.

- *Discussion of next steps and ways to keep the conversation going.* The last half hour of the workshop is devoted to discussing with participants ways to turn the workshop into more polished products (a whitepaper, grant proposals, etc.) and how to continue the conversation. Where appropriate, participants and/or facilitators are given assignments to advance these objectives after the workshop is complete.

Workshop outcomes

Given the ongoing maturation of embodiment research in the learning sciences, the Embodiment and Designing Learning Environments workshop serves to both build community among international scholars, synthesize and derive common design principles and guidelines relevant to embodied learning, and to share current knowledge with the broader community of learning sciences researchers and designers. Participants should leave the workshop with thoughtful feedback and recommendations relevant to the learning environments that they study and design. They also should have established some new collaborations that otherwise would not have formed. The success of this workshop will be reflected both in future ICLS meetings and in learning sciences journals through the increased prevalence of papers and articles discussing rigorously designed and researched learning experiences where embodiment is a central theme.

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Acknowledgments

Computer-Based Learning Environments for Deep Learning in Inquiry and Problem-Solving Contexts

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Abstract: Learning through inquiry and problem solving has been widely promoted in educational practice, and more recently in computer-based learning environments. Effective learning with real-world problems and authentic tasks, however, is not easy to realize because learning in such contexts often involves complex processes. Although relevant theories offer the foundation for understanding learning with real-world problems and authentic tasks, the design of computer-based environments and integrating them in situated learning are often sophisticated. This workshop attempts to share research and findings about how deep learning in such contexts can be empowered through effective design and implementation of computer-based learning environments, and appropriate analysis of learning in such environments.

Theoretical background

Knowledge is assumed to be better constructed through interaction with problem-oriented, socially situated environments, as claimed in situated cognition theory (Brown et al., 1989) and situated learning theory (Lave & Wenger, 1991). The two theories share a common view that situation and cognition are interdependent; cognition is a process occurring in physical and social contexts where knowledge is created and applied. Accordingly, learning in real-world situations, especially with ill-structured problems (Jonassen, 1997) and authentic, whole-task experience (Van Merriënboer & Kirschner, 2013) has become the central aspect of educational practice.

Given the constraints of classroom settings in offering learning with real-world problems and authentic tasks, computer-based environments have been increasingly explored to support situated learning in virtual environments. In spite of technology support, effective learning through problem-solving and authentic task experience is difficult to realize because learning in such contexts involves complex processes in multiple aspects (Wang et al., 2013). Such complexity may overburden learners, but is often underestimated by instructors or experts for whom many of the requisite processes have become largely subconscious because of years of experience (Reif, 2008). As a result, many learners are not adequately empowered to achieve the potential of situated learning.

It has been noted that open-ended exploration in inquiry and problem-solving tasks generates heavy cognitive load to learners (Kirschner et al., 2006), and the use of scaffolding is important to learning in such situations (Hmelo-Silver et al., 2007). This is aligned with the cognitive apprenticeship model, which claims that carrying out a complex task usually involves implicit processes; it is critical to make such processes visible for novices to observe, enact, and practice with expert help (Collins et al., 1990). Although theoretical principles offer the foundation for understanding learning in authentic situations, the design of computer-based environments and integrating them in situated learning are often associated with sophisticated and ambitious educational reform for which the implementation process is uncertain or ill-specified. While learning with real-world problems and authentic tasks is increasingly being used in educational practice, there is a concern about its weakness in instructional design and mixed learning outcomes. The mixed learning outcomes are also related to the use of examination-oriented assessment methods, which are not sensitive to learning in authentic contexts (Gijbels et al., 2005).

This workshop attempts to explore how the potential of whole-task and problem-oriented learning can be better realized through effective design and implementation of computer-based learning environments, and appropriate analysis of learning in such environments. The participants are expected to present their studies relevant to this theme in a variety of settings such as science education, professional development, and medical education, among other. In addition to sharing specific approaches and findings, we encourage open discussions on various challenges experienced in conducting such design-based research (e.g., methodological complexity, extended research process, need for domain knowledge, and commitment to advancing both theory and practice), as well as strategies to deal with the challenges.

Learning through executing real-world learning tasks is not new. It is more important than ever in today's rapidly changing world, where learners are required to deal with more sophisticated real-world problems, and have more exposure to authentic experience. The output of this workshop will advance research and practice

on how situated learning in technology-mediated environments can be adequately empowered to achieve desired outcomes.

Workshop goals

This workshop is intended to draw scholars who are interested in design and implementation of computer-based learning environments that foster deep learning with real-world problems and authentic tasks, and analysis of the learning in such environments. The workshop will provide a platform for the scholars to share their studies and findings, challenges experienced in conducting such design-based research (e.g., methodological complexity, extended research process, need for domain knowledge, and commitment to advancing both theory and practice), as well as strategies to deal with the challenges.

Workshop agenda

The workshop is comprised of multiple segments to vary the format and provide opportunities for interaction. It will start from an introduction (20-minute), during which the organizers will describe the theme and objectives of the workshop, as well as theory and research-based principles of learning in inquiry, problem-solving, and whole-task contexts to establish a common foundation for discussion. Key issues and concerns about technology-mediated learning in inquiry and problem-solving contexts will also be briefed.

The 2nd part (90-minute) will be devoted to short presentations by key contributors to share their studies and findings in specific contexts. Each presenter will highlight the key messages he or she likes to disseminate or discuss in the workshop, with a focus on effective design and implementation of computer-based learning environments, and appropriate analysis of learning in such environments.

There will be a 20-minute break after the presentations. During the break, small groups will be formed to facilitate active discussion among participants.

The 3rd part (40 minutes) will be small-group discussions by the participants. They will discuss questions and share views from multiple perspectives in smaller and more congenial environment. The workshop organizers will join the groups to facilitate the discussions. The discussion topics will be shaped by participants but may be focused on the suggested topics:

- Questions on key issues (e.g., specific design or findings, methodological issues, new assessment forms)
- Various challenges experienced by researchers in conducting such design-based research (e.g., methodological complexity, extended research process, need for domain knowledge, and commitment to advancing both theory and practice)
- Useful strategies to deal with the challenges

In the 4th part (30-minutes), small groups will rejoin, and the facilitator of each group will report the discussion output. Based on the reports, an open plenary discussion will be facilitated by one of the organizing members. The plenary discussion will focus on key issues and questions shared by different groups, together with theoretical and empirical implications of defining 'practice' for research agendas with reference to the learning sciences broadly, and to the participants' research projects.

The last part (10 minutes) will be a summary to draw together a set of approaches or strategies on how learning with real-world problems and authentic tasks in computer-based environments can be designed, implemented, and analyzed in a way that learners are adequately empowered to achieve desired learning outcomes.

With the ultimate aim of improving situated learning with technology support, the workshop will help generate a summary of pragmatic approaches for design and analysis of inquiry and problem-oriented, task-based learning in computer-based environments, to be shared among a broader community, possibly via a special issue of a scientific journal.

Workshop organizers

Minhong (Maggie) Wang is an Associate professor with the Faculty of Education at the University of Hong Kong. Her research has focused on thoughtful design, implementation, and assessment of educational technology in the contexts of workplace learning, higher education, and secondary education. Her research aims to provide learners with necessary support to achieve high levels of autonomy, confidence, and performance when they work with challenging problems, such as managing complexities involved in problem-solving and knowledge-construction processes in problem-oriented learning contexts, and dealing with cognitive overload and disorientation experienced in interaction with a large amount of online resources. Her research has featured

a theory-driven design of technologies for learning and instruction as well as the necessity for continuous development and practice for enriching design principles for technology-enhanced learning.

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Early Career Workshop

The ICLS 2016 Early Career Workshop

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Summary

The ICLS 2016 Early Career Workshop will run one and half days prior to the ICLS conference, namely the whole day Monday June 20 and Tuesday morning June 21. The aim of the workshop is to provide young, early-career Learning Sciences researchers with an opportunity to

- present and discuss their own research and receive constructive feedback about it;
- discuss and receive advice on the challenges that early career researchers face in the Learning Sciences, such as developing a career plan and research agenda, going abroad to carry out research, collaborating in the Learning Sciences as an interdisciplinary and international field that builds on a range of different methodological approaches, examining and deciding on publication strategies, organizing their work (e.g. making time to read and write), being a mentor/supervisor, engaging in scientific communities, and achieving a healthy work-life-balance; and
- build networks with fellow early career researchers interested in similar and/or complementary topics (also cross-disciplinary and cross-methodological)
- be mentored by senior researchers.

A number of activities are planned to address these topics, including panel- and small group discussions, presentations, and conversations with peers and mentors, as well as social activities to meet and build relationships with fellow researchers. Mentors are experienced researchers in the Learning Sciences from all over the world. Depending on availability of funds, there may be support to offset some of the costs for accommodation, meals, and registration, as well as travel stipends.

Leveraging Classroom Talk to Promote Educational Equity

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Student agency in learning conversations

My research focuses on teaching and learning through dialogue. There are two core issues that drive my research: (1) understanding the complex social reality of classroom dialogue (2) leveraging these insights to design teacher learning tools to teach for educational equity. At the center of these issues is the overarching principle that there is a need to understand the conditions under which *most* learners (especially those of the greatest need) learn. We need to understand how educational inequities are structured, constructed, and reproduced, in order to develop approaches and supports for teaching and learning that can advance educational equity. This position follows from decades of research that has documented that the problem of educational equity is a problem of *who* has access to content, instruction and learning opportunities that can increase learning in the short-term, and make a difference on life chances in the long-term. Thus in my work, I seek to understand the learning experiences of *historically* and *contemporarily* underserved learners, and teachers that serve them, to design for disrupting the reproduction of educational inequality.

In my research I have been examining the ways in which "access" to education is structured at the micro-level, in teaching and learning interactions (e.g., classroom dialogue, and learning dialogues more broadly). In my doctoral research which focused specifically on recent immigrant, refugee asylum seekers to Scotland and their experiences of informal learning in museums, I examined the ways in which opportunities to engage in the target language (English) were socially structured and personally maintained. By socially structured, I am referring structures that position immigrants, refugees and asylum seekers in particular ways with respect to language, e.g., linguistic isolation by way back-stage work. By personally maintained, I referring to the interaction between where one is positioned within the social structure and how they begin to position themselves (Clarke, in preparation). In addition, in this research, I examined the ways in which engaging in informal language learning in museums structured to promote "access" to language learning opportunities post-migration impacted the process of social exclusion and linguistic isolation.

In my post-doctoral research, I have been involved in a large-scale learning sciences study of dialogic instruction – instructional dialogue where teachers carefully orchestrate classroom dialogue to foster student thinking and reasoning about subject matter. I came to this work with the questions raised by my doctoral research on identity processes and learning, and the ways in which learning opportunities are structured at the micro-level. In parallel to our longitudinal effort to study supporting teachers in learning how to lead academically rigorous discussions in math and science, I focused a set of investigations within this project on understanding the nature of teaching and learning conversations in the high-need schools in which we were working, which served primarily populations from non-dominant communities. In this work, I have been examining at the micro-level the ways in which teachers structure students' engagement in dialogue, and the ways in which these structures promote or deny access to science learning in high-need schools (Clarke, 2015; Clarke, Howley, Resnick & Rosé, 2016). Insights from this research indicate that there is need to disrupt a culture of low expectations (teachers' attribution of the students they serve) *and* support the development of pedagogical content knowledge, not simply one or the other.

Teacher agency for leveraging talk for educational equity

Examining the barriers and enablers to student engagement in learning conversations has naturally lent itself to an interest in teacher learning and educational design. Using a learning sciences lens, I have been examining the process of teacher change in the way they use talk to foster student thinking over time. I have conducted in-depth case study of a single teacher from our longitudinal study that had shown measureable changes in dialogic instruction over three years (Clarke, Resnick & Rosé, in preparation). Thus, through this case study, I sought to examine the process of instructional metamorphosis from didactic towards dialogic in science, in an urban school setting. The dataset included transcribed observations of class discussions over three years (70 total) and two interviews with this teacher. Drawing on the professional development framework of the longitudinal intervention, Accountable Talk (Resnick, Michaels & O'Connor, 2010), I examined how the quality of classroom dialogue changed along three dimensions over 3 years: knowledge building, reasoning building, and collaborative reasoning. I used several discourse and computational analytical methods to examine the process of change. Preliminary findings show that while the three dimensions were developing simultaneously, their change trajectories varied. With respect to reasoning building in discussions, once the teacher began to elicit reasoning from students in year 2, the discussions he lead became progressively reasoning-oriented. Examining

the conversational exchanges between teacher and student show that when the teacher elicited reasoning, students explicated their reasoning. Likewise, when the teacher elicited recitation of facts, students recited facts. This finding, along with change trajectory findings, suggest that as the teacher began to try out more conceptually demanding questions, and students responded with conceptually deeper responses, the teacher gradually began to raise the cognitive demand in his discussions over time. Together these findings help to highlight the co-constructive nature of classroom discussions, and the agency that both teachers and students have for reshaping the discourse culture and academic demand of classroom.

In addition to studying the process of change, I have been collaborating with computer scientists to develop educational technologies for teachers to support learning about to leverage talk to foster student thinking about subject matter. The goal has been to design teacher supports that disrupt the culture of low expectations and inequitable access to high-end instruction in high-need settings. Towards this end, I co-developed a technology with Gaowei Chen (University of Hong Kong), the Classroom Discourse Analyzer (CDA) (Chen, Clarke & Resnick, in press). The CDA uses discourse analytics to visualize classroom discussions as way of providing data-driven feedback to teachers about their own instruction. The pilot field test of the CDA with teachers learning how to use dialogic instruction in their classes showed that these visualizations made salient features of the classroom discussion for teachers to reflect on. When teachers were observed teaching one month following these reflective discussions, we observed changes in the way they facilitated discussions, which aligned with their reflective discussions. These pilot findings provide a promising direction for theory-driven feedback to inform teachers' continuing professional development.

In an effort to support teachers' generative learning about dialogic instruction, I have been developing an educational technology designed to support teachers pedagogical reasoning in dialogic science discussions (Clarke, Gerritsen, Grainger & Ogan, 2016). We conceptualize pedagogical reasoning as the reasoning processes that teachers are engaged in the midst of instruction, that shape their sense-making about student ideas, subject matter content, their instructional goals, and their pedagogical repertoire, and inform their instructional decisions as a consequence. In the first phase of this work, we developed and administered a high-fidelity multimedia survey instrument populated with segments of class discussions and open-ended questions to expose 1) teachers' reasoning about student thinking in science discussions and 2) what pedagogical moves they would make in light of their reasoning to advance the discussion. The findings show distinct qualitative differences in the way novice and more experienced teachers *see* dialogic and conceptual processes in science discussions. They help to identify places where teachers may need support in developing their pedagogical reasoning in science discussion, which we aim to build on in future work. Through this line of work, I aim create supports to teachers that helps to narrow (or optimistically, close!) the gap between professional learning with teaching practice in high need settings.

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The Social Organization of Play, Embodied Cognition, and Failure in STEM Education

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A central, unresolved challenge in the Learning Sciences is to understand how cognition and knowledge construction take place through social interaction in ecologically valid learning activities. This question brings together theoretical and empirical contributions in epistemic cognition (Hammer & Elby, 2002) and situated cognition (Lave, 1988), and takes into consideration how students and teachers organize their activity to engage one another and think together. Given the growing support for design-based research, which honors the dialectical relationship between learning theory and practice, and given the group of Learning Scientists who have recently organized a volume on the integration of theories of knowledge analysis and interaction analysis (diSessa, Levin, & Brown, 2015), this continues to be a pressing question in our field.

The two topics that I study in my research are embodied play/games and stories about failure. Researchers occasionally study play through fine-grained, multimodal interaction analyses of talk and action, but researchers typically study students' and teachers' ideas about failure in laboratories and on surveys. Moreover, most considerations of social interactions around these topics, to borrow an observation from Stevens and Enyedy (2015), have focused on how collaboration within a learning activity leads to relevant distal and proximal outcomes measured in removed settings. That is, collaboration is often seen as a means to an end, not a fundamental process in its own right. I have aimed instead to understand learning as an integral part of interaction, as an ensemble of resources that stretches across people and across material and cognitive resources.

Whereas prior work on situated cognition and apprenticeship learning has recognized broad learning trajectories (e.g. movement from the periphery toward more central participation), I think that research in this tradition needs to continue to unearth the second-by-second assembly of collaborative learning for two reasons: (1) interaction analyses of knowledge construction can recognize multimodal patterns that inform the design of new learning technologies and lesson plans; and (2) to the extent that participants can reflect on the multimodal details of their inquiry processes, interaction analyses of knowledge construction can guide what teachers and students notice about their own situated actions and empower both parties to modify their learning trajectories.

Learning through play

Play is nature's implicit pedagogy (Steen & Owens, 2003). Despite that the construct has proven slippery to define over the years (e.g. Huizinga, 1950), we all recognize play as a powerful way to facilitate learning, especially with young children disposed to immerse in new identities and flout handed-down rules. The value of play goes beyond motivation. Players are known to argue about the rules that govern the activity (Sidnell, 2011), a practice that maps well onto the style of argumentation valued in science education. As part of a larger research initiative known as Science Through Technology Enhanced Play, or STEP (Danish et al., 2015), I am working with a team of researchers to understand how play invites students to move back and forth between their roles as students, inanimate entities in the target phenomenon, and experimental scientists.

To understand how structured games and open play in science education facilitate different types of inquiry across these layered roles, we are working with theories of keys (Goffman, 1974) and theories of conceptual blending (Fauconnier & Turner, 1998), frameworks compatible with research on third spaces (Gutierrez, Baguedano-López, & Tejeda, 1999). In the STEP interface, for example, students each become a single particle in a simulation, and with their full bodies interact with one another to create different states of matter. The experience of being in science class is keyed (or transformed systematically) as a participatory simulation, keyed again as open play or as a rule-based game, and keyed yet again as an occasion for controlled experimentation. With close analyses of how teachers and students use talk and body to activate, background, foreground, and blend keys, our research team is developing a sense of how participants control the boundaries of play and how play advances inquiry.

As we move forward with this project, we are merging the play and game conditions to track how features of each key maximize the potential for role-play in science education. Furthermore, in a way similar to how researchers have asked teachers to become aware of and revise the initiate-respond-evaluate (IRE) sequence, one goal of this research is to help teachers become aware of how they and their students are foregrounding and backgrounding keys, and how different configurations of keys at different stages of the learning trajectory and explicit discussion about keying norms could set the stage for productive science inquiry.

Failure stories

The second thread of my research agenda focuses on how students respond to failure in school. Experiences of failure are frequently so negative that students shut down, lose agency, and develop low self-efficacy and

learned helplessness. Surrendering too quickly to obstacles is particularly unfortunate, given experimental evidence that initially "getting it wrong" ultimately breeds deep and sustained learning (Kapur, 2008). In the very moment that failure presents itself, students and educators commonly construct narratives about the causes of the error and possible resolutions. Because failure stories are often constructed in public between multiple people (Ochs, Taylor, Rudolph, & Smith, 1992), learning interventions can promote reflection on (and ultimately revisions to) the failure storytelling process. Stories about failure are valuable because they drive motivation and provide actionable roadmaps for planning learning.

I spent four months recording students and tutors' conversations during math homework at an after school program, zeroing in on the moments when either the student or tutor flagged an obstacle. Using multimodal interaction analyses of a small number of co-constructed stories about failure in this setting, I have started to develop a framework for understanding the timing, division of labor, and causal theories that factor into stories about failure. I see this study as an essential starting point for a longer program of research. Close qualitative analyses of discourse, in this case stories about failure, establish a sense of the baseline practices of the community on which new learning interventions can build. Tabak (2004) has similarly highlighted how the endogenous organization of a school community's activity becomes the territory through which the exogenous design of the researcher takes shape.

With this first stage of the research project completed, I am working with the same after school program on a multi-year intervention that aims to embolden young students' productive practices of failure storytelling in computer science, a field in which experts practice candid, pervasive, and collaborative discourse around errors ("bugs"). The plan is for a team of researchers and practitioners to implement cycles of design-based research involving three interventions: setting new norms around encountering, interrogating, and practicing expert debugging practices; leading instructor education workgroups focused on helping instructors notice the structure of failure stories and rehearse discourse-based responses; and building coding software that gives students metadata on their struggles and provides authentic debugging resources.

Summary

To respond more directly to the question that opened this piece, I have found that recognizing the discursive practices that organize immersion in different roles during play, and likewise recognizing discursive practices that ground collaboratively constructed accounts of failure, continues a long-running challenge with respect to research and practice. Discourse happens quickly, often below the radar of attention, and under pressure from other aspects of activity. The upshot is that we need to understand to what extent teachers and students can become aware of these micro processes that ground learning. This is not an altogether new challenge, but one that I believe warrants more attention to how we can design teacher education workshops, and even further, how to communicate these insights to students to give them agency to design their own learning trajectories.

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Supporting Students' Development of Integrated Knowledge Incorporating the Content and Practices of Science

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Theoretical framework

The *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013) laid out a possible trajectory for students' learning including the connections that students might make across grades and content areas, through the use of crosscutting concepts (CCCs) and science and engineering practices (SEPs). The NGSS describe the CCCs as the themes of science that cut across disciplines, such as systems and system models, scale, or energy and matter. The SEPs are the things that scientists do to develop and refine their understanding of a phenomenon including asking questions, developing scientific explanations, or developing and using models. While the SEPs are considered the practice of science, CCCs often get grouped with the disciplinary core ideas (DCIs) as part of the science content. My research focuses on how we can support teachers to develop teaching practices and learning communities that promote students' use and understanding of the SEPs to support a deeper understanding of science content (DCIs and CCCs). When someone learning science develops knowledge in this way, we call that knowledge of content as represented using science practices an integrated understanding. In addition to examining the teachers' learning about teaching practices to support students' development of integrated understandings, my research also looks at student learning over time, and how students' conceptual models represent an integrated understanding of the science content. In the context of the NGSS, each standard, or learning performance, includes a DCI, CCC, and a SEP together in a single statement. While the learning performances describe candidate combinations of the three dimensions, there are not any suggestions for how instruction might proceed or what expert understanding of these standards might look like. Many researchers have examined how different science practices can support students' development of deep learning about science content (e.g. Scientific Explanation: Songer, 2006; Modeling: Schwarz & White, 2005). This work adds to that foundation through examining how CCCs can be incorporated into sense-making activities. This work examines the tools that support students to develop a deep understanding of the content knowledge, and, simultaneously, the practice of science. Using an understanding of student learning grounded in the work of Vygotsky (1978), where learning is both a social activity and one dependent on tools to support the learner, this work examines the tools that support students to develop a deep understanding of the content knowledge, and, simultaneously, the practice of science. My research takes two angles to examine how we might support students to develop Next Generation understanding of science.

Learning and opportunities to learn associated with an NGSS curricular unit

The first approach uses design based research to examine the development, refinement, and implementation of curriculum materials designed to address NGSS learning performances. This research works towards answering the question, how can teachers support students to develop integrated understandings of science content? My research has examined the learning and opportunities to learn associated with the enactment of a curricular unit, co-developed with the classroom teacher, focused on one particular NGSS learning performance. Building on the work of others this research starts with a curriculum designed to integrate science practices into their learning of content. During the enactment of the curriculum the teacher and the researcher suggested revisions to the lessons in alignment with what they observed of student learning. The data is composed of scans of the students' work, video of the full classroom, video of a small group within the classroom, and individual interviews with students and the teacher. This research is focused on defining what an integrated understanding looks like, and describing the characteristics of teaching and learning that integrate the three dimensions.

Initial findings show the potential for the CCC to play two roles in supporting students to make sense of content. The CCC can serve as both a tool that students can use to clarify a science concept, in this case ask questions about aspects of a watershed that make it a system, or, they can also serve as a tool for labeling components in a conceptual model of the concept, supporting a clearer more meaningful representation of the content. These two roles, provide an initial description for how the CCCs might be used to support student learning. This research provides an indication of areas where the CCC could potentially be used to support students' learning when used explicitly throughout a lesson or unit.

The unit was taught in a 6th, 7th, and 8th grade combined class, which means that all four sections of the class were taught the same material to students with varying age and experience with science. A second article, in development, is focused on the ways that the students' models changed during the course of the unit. This work,

similar to other work (e.g. McNeill, 2011) shows that students do not always appear to move in a linear path forwards, often they get stuck, or the progress they made was not entirely accurate. The students' models did not always show improvement, in fact several students had an inaccurate representation before they began to represent more normative understanding. The data collected to show students' changing understanding during the unit included interviews with students associated with their work. During these interviews students were asked to describe their models, how their model had changed since their last model, and why they believed that their model had changed. Some of the students attributed differences in their models to learning that took place during the class, and to specific activities. These responses indicated that some students were metacognitive about their changing understanding. This research also has implications for how teachers might focus instruction, and how students might learn to express knowledge in light of the NGSS.

Supporting beginning teachers to develop NGSS aligned instruction

The second line of research uses a qualitative case study approach to examines how beginning elementary teachers might manage to develop lessons and units that align with multiple sets of learning standards, including both the NGSS and state standards, in a state that has its own local science standards. This research is focused on answering the question, how can we support pre-service and beginning teachers to navigate two sets of educational standards? The beginning elementary teachers' methods courses use a high-leverage teaching practices approach to support the teachers' development of knowledge related to the practices of teaching. Our study focuses on two HLPs: "setting long- and short-term learning goals for students referenced to external benchmarks" and "designing a sequence of lessons towards a learning goal" (Teachingworks, 2015). One main assignment in the beginning teachers' science and social studies methods courses is the decomposition of the practice (Grossman et al., 2009) of planning. The courses provide a structured environment in which students can develop and test their first lesson plans.

This project, will describe pre-service teachers' thinking about standards and lesson development during their methods course, student teaching, and first teaching positions. The science portion of this project will be examined in conjunction with a social studies project, including the same students. Through focusing on the beginning teachers' changing understanding over time, we hope to be able to describe various influences that play into their learning about the practice of planning to teaching. To do this, the project will record student conversations about planning during class, interview students, and collect pairs of lesson plans and video of the students' instruction. Across the data sources, we will examine how science practices are integrated with science content, and how the teachers think about planning science lessons. The findings from this project will be used to develop tools to support students in aligning their instruction with multiple sets of standards, both for short term and long term learning goals. This research has implications for how we support beginning teachers to successfully plan lessons designed to accomplish both short and long term learning goals, particularly in times of transition between standards for student learning.

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An Emerging Research Agenda on Humanistic Learning Communities

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Introduction

My research can be broken down into four interrelated themes: A sociocultural approach, learning communities, group practices and norms, and identity. Underlying these themes is my personal interest and commitment to transforming learning and empowering learners in schools through rigorous learning sciences research. As my research has evolved over the past years, I am beginning to rise-above these four themes and see that my long-term contribution lies in articulating a new theoretical framework on Humanistic Learning Communities. In this summary, I will first elaborate upon the themes then try to integrate them to show this emerging research agenda.

Sociocultural approach

My research has been guided by sociocultural views of learning. While the meaning of sociocultural in itself is complex and open for negotiation, at the most basic level I consider this perspective to be one that considers learning as participation, avoiding the knowledge-as-object metaphor expressed in 'acquisitionist' discourse (Sfard, 1998). Approaching learning as participation is a commonality among the other themes presented here. For example, the process whereby people learn how to participate in particular cultures, or enculturation, was the focus of my doctoral dissertation and ensuing research (Hod, 2015; Hod & Sagy, 2015). I am currently engaged in a study that explores students' developing sociocultural ideas as they study within a NAPLES Master's program. Part of the complexity of this research is that on one hand it is not easy to define what sociocultural means; on the other, students' ideas are situated within their studies and therefore they express many sociocultural ideas informally. The potential contribution of this research is developing a framework showing how sociocultural ideas begin as situated within students' learning experiences and become increasingly abstracted across situations.

Learning communities

Learning communities are a translation of sociocultural ideas into educational practice (Bielaczyc & Collins, 1999). Guided by my interest to transform learning and empower learners in schools and classrooms, all of my research has been situated within learning communities to better understand learning within them. At ICLS in Boulder, along with Kate Bielaczyc and Dani Ben-Zvi (2014), we co-founded a collaboration of international researchers on learning communities (CIRCLES) to re-invigorate research on this central learning sciences theme and to refresh old syntheses that take into consideration innovations in learning communities. We are currently co-editing a special issue in *Instructional Science* with this explicit goal. In addition to these efforts, I am co-leading a study group on learning communities that aims to review their conceptualizations and designs.

Group perspectives on practices and norms in learning communities

In the past two years, I have published two empirical articles that contribute new perspectives on learning communities, one from an individual unit of analysis and the other from the group level. Common between these is that they show the relevance of classical research on groups and group dynamics (Tuckman & Jensen, 1977; Yalom & Leszcz, 2005) to learning communities. In the first study (Hod & Ben-Zvi, 2014), I explored how students' participatory practices transformed over time within the learning community where they studied. The framework was an adaptation of social microcosm theory, showing how participants make guided but intentional changes to their collaborative learning practices on their way to becoming fuller members of the community. In the second paper, I showed how a group developmental stage framework is relevant to classroom sized learning communities, and particularly how the transition from the storming to norming stage can explain the process whereby students assume collective responsibility (Zhang, Scardamalia, Reeve, & Messina, 2009).

Identity

In addition to my research on learning communities, I have taken a recent interest in the construct of identity. My prior research, such as examining students' transforming participatory practices, has revolved around this idea, but hasn't touched upon it directly. I have found identity as useful in capturing the type of transformative and sustainable learning that I have been researching within learning communities (Lave & Wenger, 1991).

Particularly, I have been influenced by the work of Sfard and Prusak (2005), who view identity as a collection of stories about a person. Taking this discursive perspective, I am currently engaged in an empirical study of teachers who develop their identities as learners within a continuing education course, and examining how these teachers express these stories within their practices and identity stories about themselves as teachers in their own classrooms. This research answers the challenge that Jean Lave set out in her keynote address in ICLS 2014 about examining learning across communities. Additionally, I have started a recent collaboration with Jianwei Zhang, from the University at Albany, to research students' identities as knowledge builders. Again, identity is the central construct because it captures the sustainable type of learning that is the goal of knowledge-building communities (Zhang, Hong, Scardamalia, Teo, & Morley, 2011), but it under-researched in this context.

An emerging research agenda

Taken together, my research on learning communities touches upon some of the most central ideas within the learning sciences: the sociocultural approach, identity, practices, and norms (Sawyer, 2014). A careful reading of my work reveals signs of a humanistic viewpoint on learning emerging. To start, by taking a sociocultural approach, I have conceptualized the learner within a process of becoming a certain type of person. Thus, I have given great attention to the social and emotional aspects of learning so as not to factor out these aspects of *being*. Ideas from group dynamics contribute to this perspective, as I have considered the agency and responsibility of individuals and groups to guide their own learning. Finally, I have put a great deal of focus on (and been drawn to) studying learning within a community that has its intellectual roots within a humanistic-existential perspective (Lyon, 1971). It is my intention, in the years to come, to more fully articulate this emerging agenda. I hope that the ECW will provide an opportunity for me to find ways to advance these ideas.

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Learning Through Teaching: Towards a Socio-Cultural Theory of Teaching Practice Development

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Overview of research goals

My research agenda is to better understand how individual teachers' learn and develop their new instructional practices through their classroom interactions, in which both students and teacher actively participate. As a part of this research agenda, in this particular study I explore the ways in which a mathematics teacher's instructional practices shift and develop towards becoming more responsive to student mathematical thinking.

Theoretical perspectives

Ongoing reform efforts in school mathematics consistently recommend students' active participation in activities and discussion in classrooms. A substantial body of research has addressed the importance of instructional practices that are related to "student-thinking responsive teaching" (Kim, 2015, p. 7), an instructional practice in which teachers consider how to understand, make effective use of, respond to, and provide formative feedback on emergent student mathematical thinking (Ball, 1993; Black & Wiliam, 1998; Black, Harrison, Lee, Marshall, & Wiliam, 2004; Fennema, Franke, Carpenter, & Carey, 1993; Hammer, 1997; Jacobs, Lamb, Philipp, & Schappelle, 2011; Kazemi & Franke, 2004; Lampert et al., 2013; Shepard, 2000; Sherin, Jacobs, & Philipp, 2011). Teaching, especially in the reform context, is more than an individual cognitive activity. It is situated in a participatory context with other individuals, particularly students, and with a type of specific subject matter (Lampert, 2001); it also constantly adapts as classroom members interact with one another and encounter new topics and problems. From the perspective of student-thinking responsive teaching, emergent student thinking in specific topics also interacts with the establishment of collective norms, the teacher's instructional activity, and students' interactions during discussions.

In this complex context, a methodological challenge has emerged to investigate the development of individual teachers' teaching practices within and across collective practices. The analytical framework that Saxe (2012) suggested is a powerful tool for understanding the interplay between individual development and cultural processes by resolving the methodological issue. However, when the development analysis of an individual teacher's instructional practices is brought to the forefront, another methodological issue arises. The teacher has different goals, authority, and positions that students do in collective activities in which both teacher and students participate. What does the relationship between collective practices and a teacher's development of his or her individual practices mean? This study is the first step toward better understanding on this process by investigating how individual teachers' development of new teaching practices in collective practices—particularly those that focus on being more responsive to student mathematical thinking, where emergent student thinking is a source for teacher learning and development.

Methods

Data sources

Eight mathematics teachers from two schools in two urban school districts in the San Francisco Bay Area participated: four from a middle school and four from a high school. Various data sources were collected over the 2013–2014 school year. As the main data source, there were two kinds of classroom observations: regular teaching observations (4–6 days each at the beginning, middle, and end of the school year) and teaching observations (in which each teacher implemented 3–5 lessons over the course of the school year). All classroom observations were video recorded, and field notes were taken. I supplemented these observations with audio recordings of semi-structured interviews with the teachers both at the beginning and end of the year, and with recordings of professional development meetings.

Data analysis

In the author's previous work (Kim, 2014; Kim, under review), the teaching practices and student responses are categorized by what the student-thinking-responsive teaching practices would be. Here I provide a summary of the analytical categories (see Table 1 and Table 2). While the previous work (Kim, under review) presented individual teachers' change in practices in their use of curriculum materials with a focus on their pedagogical goals and practices, this current work attempts to analyze the ways in which teachers develop new instructional

practice—student-thinking-responsive teaching—in the context of social interactions with active participants, students.

Table 1. Summary of analytical categories for student-thinking-responsive teaching

Teacher-centered teaching practices involves:	Student thinking responsive teaching involves:
(a) Teacher Explaining (b) Teacher Restating/Evaluating/Clarifying (c) Probing Procedural Process Questions	(d) Soliciting Mathematical Ideas and Strategies (e) Eliciting Students' Reasoning (f) Promoting Student Discussion

Table 2. Summary of analytical categories for student discourse

Directly answer to the teacher (1-1 respond)	Student discussion
(a) Procedural Types of Answers (b) Explaining Own Reasoning	(c) Procedural Types of Talks (d) Justifying Their Own Reasoning (e) Building on Each Other's Ideas

Plan for next steps

My analytical framework is in the process of continuously developing in iterative passes through my theory, hypothesis, construction, and observation (Kerlinger, 1973; Yin, 2009). With existing findings, I plan to further investigate teacher learning and development through practices by tracing and unpacking the process of development of the selected individual teachers' instructional practices in the context of social activity.

Conclusions and implications

This study potentially opens a new avenue for the research on developing teaching practices through practices. Better understanding on this process is critical to support teachers to become more responsive to student thinking not only for their student learning and but for their own learning as professional development.

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How Preparation Activities Affect the Process and Learning Outcomes of Peer Collaboration

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Introduction

My interest in investigating how peer collaboration affects learning first grew from my experiences as a university instructor of introductory educational psychology courses. I believed that engaging in conversations was a powerful way to learn, so I created classroom activities and assignments that required students to explain ideas to one another, critique and evaluate each other's claims, and reflect upon how other's contributions changed their thinking. Before researching some of the practices that foster collaborative learning, I was already doing them. I watched my own students experience the learning benefits of peer collaboration, and I became driven to understand how the design of collaborative activities could invoke the mechanisms of learning.

The research that I conducted during my graduate program showed that designing tasks to cognitively engage students in different ways affected both how they collaborated and how much they learned from the collaboration. I manipulated the design by requiring students to generate ideas around concepts not formally learned or use given concepts in an application task, and by differentiating the structure of the activities within the task. Examination of learning outcomes pre, during, and post the learning intervention showed that the extent to which students learned the concepts varied at different stages depending on the design. This work has led to my current focus, which is to address how different individual "preparation" activities affect the process and learning of collaboration in authentic classroom settings.

Developing a theoretical framework

I am currently investigating how task design invokes the mechanisms of preparatory activities, and how those activities invoke collaborative learning mechanisms and ultimately affect learning outcomes. This work takes place within a program of research that I am developing in Singapore, which I call Preparation for Future Collaboration (PFC). As Principle Investigator of a project focused on PFC, we are assessing how different preparatory task designs affect collaborative problem-solving and learning of upper primary students in classroom lessons on environmental sustainability. In another set of studies, we plan to examine the how the degree of generativity of preparation tasks affects learning after collaborating of secondary students in mathematics classes. The development of the PFC theoretical model aims to further unpack how preparation activities impact the collaborative learning process.

This theoretical focus is grounded in two related, but distinct, conceptions of learning: the Preparation for Future Learning (PFL) paradigm (D. Schwartz & colleagues) and Productive Failure learning design (M. Kapur & colleagues). Although the PFL work is centered on preparation to learn from future lecture, it provides the theoretical foundation for my work on preparing for learning from future collaboration in the following ways. 1) The act of generating knowledge in a preparation phase (e.g., via invention, Schwartz & Martin, 2004; contrasting cases, Schwartz & Bransford, 1998) requires a learner to activate existing knowledge that is relatable to the concepts yet-to-be learned, which then 2) promotes a "readiness" for future learning by priming the learner to incorporate relevant information from the subsequent task into existing knowledge structures (Schwartz, Sears, & Chang, 2007). One major difference in learning from a future collaborative task is that the canonical representation(s) of a target concept may or may not arise from discussions of learners with naïve representations. This is one facet that is precisely of interest. My prior work has shown that students can individually solve difficult problem tasks after collaborating to the same degree as those who are initially provided the canonical forms, without ever receiving explicit instruction of the forms. This leaves an open question of how the inclusion of direct instruction, after preparing by generating knowledge then collaborating, affects learning.

The learning design incorporated in my work is closely aligned to Productive Failure. Kapur and Bielaczyc (2012) explicated their design principles, asserting that there is a two-phase process to learning from Productive Failure. 1) *Exploration and generation* creates opportunities for students to recognize what they do and do not know, tinker with ideas, engage in problem-solving, and discuss ideas and solutions with peers, followed by 2) *knowledge consolidation and assembly*, in which the canonical solutions to problems are presented in direct instruction, offering students the chance to compare their own solutions and conceptions with the correct ones and refine their representations of the target concepts. The PFC learning design invokes these

learning mechanisms in similar ways, however, across three rather than two phases of instruction as shown in the figure below:
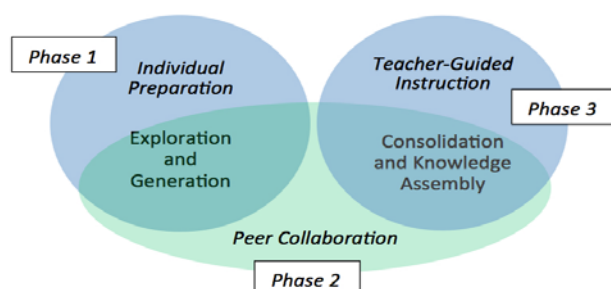
Figure 1. Preparation for Future Collaboration learning design.

Research design and methods

I am investigating the PCF model through design experiments (Brown, 1992), to which we test and evaluate our instructional interventions in real classrooms, redesign for improvement, and reexamine their effectiveness, in close partnership with and involvement from teachers, all while aligning with existing school curricula. I use experimental designs (and also plan to use quasi-experimental designs) to compare instructional conditions, and mixed methods analyses to assess and quantify qualitative student productions (including student-generated solutions to problem tasks, discourse during collaboration, and written reflections and ideas). The goal is to shed light on both the learning mechanisms at play in our activities, from preparation to collaboration to teacher-led instruction, and the learning outcomes across all instructional phases.

Final words and conclusion

All of my current work is begin done with at-risk students, as a point of personal advocacy. This population of students can be particularly vulnerable to the impact of classroom experiences, whether positive or negative (Finn & Rock, 1997; Rumberger & Lim, 2008). The PCF model and corresponding learning activities are designed in consideration of affective supports. For instance, they encourage students to voice their own ideas and be heard by others, which tells them that their ideas matter and that they are valued in the classroom community (Toshalis & Nakkula, 2012). I believe that using design experiments and mixed-methods approaches allows me to address my research questions through the lens of the student-as-learner, while considering the practical challenges that teachers face when teaching and managing a classroom.

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Acknowledgments

Exploring How Teachers' and Students' Personal Alternative Conceptions With Scientific Concepts Influence Teaching Practice

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Research summary

My research focuses on how teachers approach science instruction when they are aware of their own and their students' personal alternative conceptions with major science concepts like evolution by natural selection. As individuals who are charged with the learning and instruction of scientific concepts to students, teachers are advised to become familiar with their students' alternative conceptions so that they may be leveraged as resources within their classroom instruction. However, it is increasingly apparent that teachers are unaware or unsure of how to incorporate students' alternative conceptions into instruction.

Other factors within the teacher knowledge base affect science instruction as well. Lack of teacher subject matter knowledge (SMK) is among these different factors, but other factors include knowledge and beliefs about different science concepts and science learning in general and knowledge of learners (including their prior knowledge and alternative conceptions). These factors are not often closely examined within the context of the classroom. That is, surveys, questionnaires, and other quantitative instruments provide a general idea that teacher understanding and scientific beliefs are factors that affect classroom instruction, but a rich descriptive examination of what having this understanding and knowledge (or lack thereof) looks like from a classroom perspective needs to be fully articulated. Classroom descriptions, such as these, will potentially reveal valuable insights about how teachers think of and plan science instruction and how their students' alternative conceptions influence their instructional decisions. In addition, they will potentially inform how science educators (including content experts) and professional development coordinators should approach pre- and in-service teacher science understanding and preparation by providing real world examples of the issues teachers encounter when teaching difficult-to-learn science concepts in their entirety.

Theoretical framework

My work is grounded in the understanding that students build their knowledge of various concepts based on their existing ideas and knowledge; therefore, knowledge of student conceptions (KOSC) is an essential component of teacher pedagogical content knowledge (PCK) (Shulman, 1986). Knowledge of students' conceptions is essential for teachers in two currents of constructivist thought, if for different reasons. Student ideas that differ from normative scientific understandings can be seen as "misconceptions" that are obstacles to be overcome (e.g., McCloskey, 1983). If instead envisioned as resources, student conceptions or fine-grained ideas can be used as a basis for further growth and development of ideas and ultimately lead to meaningful understanding of scientific concepts (Elby, 2000; diSessa, 1994; Hammer et al., 2005; Larkin, 2012; Scott, Asoko, & Leach, 2007). In both perspectives, teachers need to be familiar with their students' ideas in order to design instructional activities that confront these ideas or draw attention to the contexts in which these ideas are useful or inappropriate.

Research to date

Using a conceptual framework set forth by Magnusson, Krajcik, & Borko (1999), my dissertation work set out to explore two specific aspects of the science teacher knowledge base in hopes of determining and eventually teasing out the role SMK was playing in teachers' KOSC when teaching a difficult-to-learn scientific concept—evolution by natural selection. This exploration was partially completed by reporting the SMK and knowledge of students' natural selection alternative conceptions from a group of high school science teachers through the use of the Conceptual Inventory of Natural Selection (CINS) (Anderson, Fisher, & Norman, 2002).

The CINS—like most concept inventories—is a paper-and-pencil instrument developed specifically to test conceptual understanding. It uses common student alternative ideas (determined by empirical research) as answer options, in addition to the normative scientific explanation. In my work, the CINS was used to determine teachers' KOSC by asking them to predict their students' most common incorrect answers and then comparing their predictions to the actual student answers on the CINS, thereby operationalizing the teachers' KOSC with a "prediction accuracy" measure. This proposed methodology of using a single instrument that is applied to teachers and their students could be useful in larger-scale studies that examine the relative impact a teacher's PCK and SMK has on student learning, for a variety of key topics in the secondary science

curriculum. Furthermore, my proposed methodology makes KOSC more explicit and accessible with the use of a single measure and allows teachers to use it as a reflection tool that will assist them in identifying which student alternative conceptions are aligned with their existing KOSC and which are not.

In order to complete my exploration, an examination of these four teachers' individual classroom practices (mainly through classroom discourse) was then conducted to determine whether and how their instruction on evolution reflected their KOSC. While this group of teachers was keenly aware of their students' alternative conceptions (all had prediction accuracy scores ranging from 0.76 to 0.87, where 1.0 was optimal) on evolution by natural selection, they struggled with making their classroom instruction more responsive to student ideas. In addition, this group of teachers demonstrated variation (ranging from 65%-80%) with their SMK of natural selection concepts, suggesting that SMK may not be a necessary prerequisite for these teachers' KOSC.

Future directions

I am interested in continuing to explore the classroom practices of secondary science teachers as they work to effectively leverage their students' alternative conceptions with various science concepts. The findings from my dissertation study made me realize that teachers need to be afforded more opportunities to discuss their students' ideas with their colleagues so that these ideas may form the basis of student-centered instruction. Some academic departments within various schools allow for these professional learning communities (PLC) to meet and providing a structure that teachers may use during PLCs to discuss the resourcefulness of student ideas may go a long way in increasing instructional effectiveness. Our education department has recently partnered with a charter school that serves traditionally underserved students and we envision a collaboration that could serve both the school's pedagogical and the university's research needs. Having the participation of the school's science department would extend my research work in that I could explore how teachers' SMK and KOSC compare with concepts other than evolution.

In a related manner, I am also interested in the SMK and beliefs of our preservice elementary teacher candidates, especially with regards to science topics like evolution and climate change. Traditionally speaking, science instruction at the elementary level sometimes receives minimal attention. Therefore, it is imperative that preservice teachers receive exemplary pedagogical preparation for teaching science; however, this preparation is occasionally hindered by the beliefs and knowledge (to some extent) of these preservice teachers. The research base for teacher knowledge and the learning sciences has yet to gauge the beliefs, SMK, and pedagogical approaches of elementary teacher candidates trained at a university affiliated with the Catholic Church. How these teaching candidates in this unique context make sense of major and somewhat controversial science concepts can add a rich dimension to the learning sciences and teacher knowledge research base.

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Learning-by-Making and Educational Equity: STEM Learning and Identity Development in a School-Based Makerspace

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Background and aims

In my post-doctoral project, together with Professor Kristiina Kumpulainen, we will address the challenge of students' disengagement from formal science, technology, engineering, and mathematics learning (STEM) by investigating how a novel educational makerspace called *the FUSE Studio* (Jona, Penney, & Stevens, 2015) enables, restricts and challenges students' engagement, learning and identity formation in STEM within the contexts of a Finnish elementary school. In drawing on Maker movement in which participants engage voluntarily in making and creating things together and share knowledge using contemporary technological and digital tools, the FUSE Studio represents an alternative infrastructure (Stevens, 2007) for the organization of STEM learning pathways to promote students' interest and engagement in STEM learning.

The contemporary Maker movement and the broader "Do-It-Yourself" (DIY) culture celebrates hands-on innovation, creativity, and community engagement across a wide array of genres including crafts, robotics and computing. At present, there is growing interest towards the Maker movement's educational potential in particular in the US but also internationally such as in China and Finland (e.g., Peppler, Halverson, & Kafai, in press), as it is believed to offer a powerful context to foster STEM learning and 21st century skills important for workforce development and technology literacy required from children as present and future citizens in contemporary knowledge society. However, there is little warranted research evidence to support these claims. Moreover, what counts as making and what making counts for school-based STEM learning and education remains vague and under-theorised.

In our research, we will focus on long-standing cultural and gender disparities in STEM fields, and how they can potentially be overcome. Moreover, we aim to generate valuable new research knowledge in the context of ethnographic research for documenting and assessing students' STEM learning and identity formation in school and science center based makerspaces. We hold that learning that matters is learning that lasts, and that learning that is mobilized across tasks and domains. Furthermore, we argue that documenting and assessing students' learning and identity development needs to take into account relational and institutional levels of analysis in addition to focusing on the personal level.

Theoretical framework

Drawing on sociocultural and activity-theoretical approaches, we take social practice as a core unit of analysis (Kumpulainen & Sefton-Green, 2014; Holland et al., 1998; Rajala & Sannino, 2015; Rajala et al., in press). This framing emphasises the importance of understanding learning beyond conceptual acquisition, as identity development and transformation of valued social practices and discourses. In sociocultural theorizing, learning and identity development are seen as intertwined. Learning transforms who we are and what we can do (Nasir & Saxe, 2003). Identities define how we position ourselves and our actions — through which others, in turn, position us. They are also performances we enact as we interact with others (Wortham, 2004). A sociocultural perspective on identity development depicts identity as socially situated, mediated, and produced, as well as multiple and shifting (Holland et al., 1998; Nasir & Saxe, 2003).

Research design and methods

The empirical research of this project will take place in an urban public Finnish elementary school. More than 15% of the students speak mother tongues other than Finnish or are from an immigrant background. At present, the school community is establishing a *FUSE Studio* makerspace into its premises and practices. Our methods of ethnographic data collection and analysis fall into three broad analytical levels, as described in the following.

The relational level: Microethnographic studies. We will conduct focused, microethnographic studies of students as they engage in the FUSE Studio makerspace, working with and across challenges. Activities in the FUSE Studio will be video-recorded intermittently over the three year period. In addition to documenting STEM conceptual understandings and their realizations in practices, video-based, microanalytic studies will also inform questions in relation to students' identity negotiations. Sociolinguistic and ethnographic discourse analysis (Nasir & Saxe, 2003) is used to guide our analyses.

The personal level: Longitudinal case studies of participants. We will construct longitudinal case studies of students who visit the FUSE Studio regularly over three years. We expect to have the minimum of 25 students in our data sample, informing us about how these students' experiences in the FUSE Studio are

reshaping their interests, identifications, and participation in STEM learning, also in other parts of their lives and over developmental time. In our analysis, we pay attention to how the students come to be consistently identified as a recognizable types of persons (Wortham, 2004). We also examine whether and how students' more stable identities are destabilized to give room for the emergence of new provisional identities.

The institutional level: Institutional ethnographic analysis of the integration of FUSE Studio and its practices into the school's everyday life. Before the FUSE Studio makerspace is implemented to the school, we will collect baseline data of the school and its history, including interviews with the teachers, principal, and students. These data will be supplemented by relevant documents, such as media reports and possibly already existing historical accounts of the school. We will then continue with longitudinal ethnographic field work. The field work will focus on the integration of the FUSE studio into the school's everyday life related to 1) changes in the curriculum, social organization of teaching and learning, teacher collaboration, space and time arrangements, as well as assessment of learning; 2) tensions and conflicts, and their possible resolution, that arise when the uptake of FUSE Studio collides and interacts with the the existing school culture; 3) the spreading of knowledge and learning practices generated in the FUSE Studio in the school, as well as the consequences of this spreading.

Expected results, and scientific and societal impact

This project addresses long-standing cultural and gender disparities in STEM fields, and how these can potentially be overcome. *Theoretically*, the project will illuminate the sociocultural contextualization of the FUSE Studio makerspace in a Finnish elementary school context. The findings will unpack the dynamics between the motivations that young people bring into their maker activities and the demands that these activities pose on their engagement, learning and identity formation. In doing so, the project will disclose the developmental potential of the FUSE Studio concept for individual growth, as well as for institutional transformation. *Methodologically,* we shall develop novel technologically enhanced ways of analysing ethnographic, longitudinal data on the dynamics of three interrelated analytic levels: institutional (interaction between maker culture and formal school culture), relational (learning mechanisms) and personal (learning and identity development). *Practically*, understanding what triggers young people's engagement, learning and identity formation in the FUSE studio potentiates ways of modifying pedagogical practices towards inclusivity, involving diverse students. The findings of this research will thus offer significant insights into teacher education programs, curriculum development, design of STEM learning environments, and ideally into educational policies to promote equal educational opportunities in STEM.

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Social, Perceptual, and Conceptual Factors of Learning With Multiple External Representations in Educational Technologies

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Introduction

Students learn with visual representations (e.g., pie charts and graphs in math; Lewis structures and ball-and-stick models in chemistry). Instruction in science, technology, engineering, and math (STEM) domains use visual representations to make abstract concepts accessible to students. However, visual representations can also confuse students; for instance, if students do not understand how the representation depicts concepts, or how to translate among representations. Thus, students need **representational competencies:** knowledge and skills that enable them to construct, interpret visual representations, and to translate between them. My goal is to establish effective ways to support students' representational competencies to help them succeed in STEM. To this end, I conduct empirical research that investigates (1) which representational competencies are key to STEM learning, (2) through which processes students acquire them, and (3) best to support them in instruction.

Theoretical framework

Based on my findings, I am developing a theory of the **S**ocial, **P**erceptual, and **C**onceptual factors of learning with **E**xternal **R**epresentations (**SPACER**). The SPACER theory makes three central claims.

Claim I states that STEM learning involves two types of representational competencies that require different types of instructional support because they involve different types of learning processes. *Conceptual competencies* involve the ability to map visual representations to concepts, to make inferences based on representations, and to choose appropriate representations for a given task. Students acquire conceptual competencies via conceptual processes—verbally mediated, explanation-based processes. Conceptual processes are roughly analogous to Kahneman's popular description of "deliberate" or "System 2" thinking. To support conceptual processes, instruction needs to actively engage students in making sense of visual representations.

By contrast, *perceptual competencies* involve the ability to effortlessly and efficiently see meaning in visual representations. Analogous to bilinguals who are fluent in two languages, perceptual competencies involve fluency in understanding and translating between representations. Students acquire perceptual competencies via perceptual processes—automatic processes involved in pattern recognition that are non-verbal, implicit, and inductive. Perceptual processes are analogous to Kahneman's "fast" or "System 1" thinking. To support perceptual processes, instruction can expose students to numerous varied examples of visual representations.

Claim II states that students' acquisition of conceptual and perceptual competencies follows a learning progression; that is, students acquire these competencies in a particular sequence because the acquisition of one competency helps them acquire another competency and vice versa. On the one hand, conceptual competencies can enhance the acquisition of perceptual competencies because students know which visual features show domain-relevant concepts. On the other hand, perceptual competencies can enhance the acquisition of conceptual competencies because "fluency" with visual representation frees cognitive resources that students can invest in willful, deliberate thinking. Thus, support for representational competencies is most effective if it takes into account how conceptual and perceptual competencies build on one another in a learning progression.

Claim III states that, because individual students learn at different rates, they may have different needs for conceptual and perceptual support. Therefore, support for representational competencies is most effective if it adapts to the individual student's needs in real time.

Educational technologies

Educational technologies have the capability to adapt to the individual student's needs. They do so based on a computational model that infers the student's knowledge level based on interactions with the technology. Therefore, I situate my research on the SPACER theory in educational technologies. Specifically, I seek to augment regular learning activities with educational technologies that provide individualized support for representational competencies. Imagine a student visualizing a fraction with an interactive computer-based pie chart, or two chemistry students building a ball-and-stick model. The technology may alert the math student to having confused numerator and denominator of the fraction in the pie chart; or it may prompt the chemistry students to compare their model to a virtual representation and to discuss mismatches. I refer to this use of educational technologies as **V**isual **E**xternal **R**epresentations with **I**ndividualized **T**echnologies (**VERITs**).

Empirical research

My research on the SPACER theory and my research on VERITs iteratively build on one another. On the one hand, I use VERITs to test the SPACER theory. Second, VERITs can assess students' conceptual and perceptual competencies as they develop over time. This provides insights into the nature and relationships among these competencies. In the following, I describe how VERITs have served to test and refine the SPACER theory in my current research.

My first step was to establish a methodology for developing VERITs that align with the educational practices of the given target domain. I applied this methodology to design a VERIT for college chemistry (VERIT-Chem). VERIT-Chem features conceptual and perceptual support for representational competencies and yields significant learning gains when used as part of college chemistry courses. My current research uses VERIT-Chem to investigate specific claims of the SPACER theory.

With respect to **Claim I**, my work has yielded several **instructional design principles** for conceptual and perceptual supports. *Conceptual supports* are effective if they prompt students to compare multiple representations to one another, if they engage students in discussions about how visual representations depict information, or if they ask students to construct their own representations. Further, my research describes *social contexts* that can enhance the effectiveness of conceptual supports. Conceptual supports are particularly effective if they are integrated in collaborative activities and if students receive assistance from an instructor.

By contrast, *perceptual support* should be embedded in *individual contexts* because verbalization—as common in social contexts—interferes with non-verbal perceptual processes. Instead, perceptual support should provide classification tasks with a variety of visual representations, provided in an interleaved sequence. These sequences should draw students' attention to visual features they tend to confuse. I currently investigate how to trace students' level of perceptual competencies over time so as to provide more effective visual feedback.

I also tested the **hypothesis** that providing students with conceptual and perceptual support enhances their learning. I had found initial evidence for this prediction in my research on elementary-school fractions. I then investigated whether these findings generalize to a drastically different domain and population: college-level chemistry. Lab and field experiments show that combining conceptual and perceptual support leads to higher learning outcomes, compared to either support alone, and compared to "business-as-usual" control conditions without such support.

With respect to **Claim II**, I tested the **hypothesis** that students' benefit from conceptual versus perceptual support depends on their current level of conceptual and perceptual competencies, respectively. I had found initial evidence for this claim in a lab experiment on fractions learning. Lab and field experiments with VERIT-Chem provide support for this claim in college chemistry. To my surprise, recent results even reveal potential "dangers" of providing supports in a way that misaligned with the learning progression. For example, students with low conceptual competencies who received perceptual support (instead of conceptual support) showed lower learning gains than students who received neither type of support.

Future research plans

My plan for the immediate future is to test additional hypotheses of the SPACER theory using VERITS-Chem. Specifically, I will test whether conceptual support is most effective when it is "spaced" across different social contexts (e.g., collaborative wet-labs for conceptual support, individual homework assignments for perceptual support) (Claim I). I will also examine the proposed learning progression over the course of a semester-long chemistry course (Claim II). Finally, I will test whether support that adapts to the individual student's level of representational competencies is more effective than static forms of support (Claim III).

My long-term plan is to expand my research to other domains than chemistry. I will investigate whether the SPACER generalizes to other STEM domains and refine it based on my findings. Specifically, I will investigate how the type of visual representation affects students' learning. For example, some domains tend to use visual representations with iconic features (e.g., physics, computer science, whereas other domains often use realistic photos (e.g., medicine, biology). Further, I will investigate domain-specific practices. For example, in some domains, visual representations play a "training wheel" role (e.g., math), whereas in other domains, they play an "end-in-itself" role: (e.g., chemistry, medicine).

In sum, my work addresses several issues. First, existing interventions, including educational technologies, tend not to take students' representational competencies into account. Second, they can adapt only to verbally mediated forms of knowledge (e.g., conceptual competencies), but not to non-verbal forms of knowledge (i.e., perceptual competencies). Third, they do not take into account how the social context affects learning with representations. Thus, my research bridges social, perceptual, and conceptual factors of learning with external representations.

An Inclusive Framework for Understanding the Role That Communities of Practice Play in New Digital Literacies, Barriers to Participation and Implications for Equity

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Opportunities and barriers with digital literacies

While marginalizing practices in digital play and participation have made national headlines, they have rarely been considered in terms of their impact on learning practices and digital literacies. For example, a small yet longer trajectory of literature addresses the dearth and problematic nature of gender and racial diversity in games (e.g., Everett & Watkins, 2008; Nakamura, 2013; Williams, et. al, 2008). Recent studies have started to explore whether negative and limited representations of women and non-dominant ethnic/racial groups in games are linked to social behaviors, such as gender and racial bias (e.g., Dill & Burgess, 2013; Fox & Tang, 2014). However, the discourse is mostly silent on how these effects may impact learning and participation in an array of digital literacies relevant to the 21st century workforce and educational landscape.

Emerging research in the learning sciences has highlighted the importance of considering the effects of digital informal learning environments (such as gaming), the literacies they foster and the implications for formal learning and participation in a variety of careers (e.g., Jenkins, et. al. 2009). Online gaming communities, and associated affinity spaces where individuals can create content related to their fandom, have been seen as an important form of computer-supported collaborative learning (Richard & Hoadley, 2015). However, these environments are not equally welcoming or beneficial to all; women and ethnic/racial minorities are notably less visible in these leisure spaces (Richard, 2013), in a similar vein to their lack of visibility in associated STEM fields (Gourdin, 2005). In fact, gaming has long been shown to be a pipeline to computing and related fields (e.g., Kiesler, Sproull & Eccles, 1985), and studies have found that women and non-dominant groups are more vulnerable to lowered identification and self-concept in gaming (Richard, 2013), akin to other computing domains. In other words, not having the same kinds of social capital in the digital age can put someone at a significant disadvantage in ways that contemporary formal education may not be able to fully rectify.

Related work and methods

This research focuses on understanding the ways that digital and technology-centered communities can both foster and limit access to digital literacies and pathways. In this work, three different kinds of learning communities are explored. The first is a commercial, online gaming community for marginalized players, who are mostly women, and documents how they experience barriers to equal participation in gaming but also how supportive spaces can foster equity by design (Richard & Hoadley, 2015). The second is a digital media and games content creation community for youth that is seemingly open to all, but demonstrates parallels to the commercial gaming environment in the gender discrepant participation patterns, the kinds of content created, and the visible diversity of members (Richard & Kafai, 2016). The final community is an informal learning environment where diverse youth learn how to make wearable games in a maker space (Richard & Kafai, 2015).

Three different methods were used to understand how each of the communities both foster and potentially serve as a barrier to digital learning and relevant identities. For the commercial gaming community, I performed both an extensive ethnography of digital game culture and a female supportive gaming community as a woman of color, and conducted surveys of members in both communities to triangulate themes and develop a framework (Richard, 2013). For the youth-oriented digital content creation community, we conducted extensive observations of the community for over a year, followed by web crawler searches. Finally, in the maker space community, we conducted observations, surveys and interviews, and analyzed final projects.

Findings and inclusive communities of practice framework

In both online gaming for pleasure (Richard & Hoadley, 2015) and youth digital media and game content creation communities (Richard & Kafai, 2016), we have found similar disparities, with diversity often difficult to find or discuss, individuals often not willing to disclose their gender or ethnic background, as well as being unsupported, in a variety of ways, when they do. However, we found that changing social values in gaming and computing spaces also had an effect. For example, by placing high value on women's skill development, the

female-supportive gaming community helped build cross-gender support for this goal, which measurably increased women's self-efficacy and identity in gaming and its digital literacies; it also had a positive effect on male members' investment in similar ways and served as a pipeline to careers in game development. Similarly, the maker space workshop focused on designing games that were not only digitally and physically interactive, but wearable. As such, learners had to engage in coding, designing and crafting. We found that by placing high value on crafting as part of computational production within a team, diverse skillsets were further reinforced and gender barriers break down in terms of interests (Richard & Kafai, 2015). In other words, exploiting crafting as an entry point into other kinds of skills could broaden computing, while also allowing for a safe space where multiple interests could be explored and valued (Richard, et. al., 2015).

A framework that holds promise for helping to address the disparities that result from marginalizing practices in online gaming is that of *inclusive communities of practice* (Richard, 2015)*,* which extends upon Wenger's (1999) components of social learning theory. Jean Lave and Etienne Wenger (1991) originally coined the term "communities of practice" to refer to the "legitimate peripheral participation" that occurs in hobby and practitioner communities that most learners invariably participate in at some point in their lives. Using socioculturally supportive gaming communities as a model, I have uncovered certain practices that would be important for the learning sciences to consider, in similarly ways that they have in computing (Margolis, et. al., 2010). For example, I measured and found that community connectedness and perceived support, domain identification and self-concept – which have all been seen as important "non-cognitive" factors that reinforce learning – affect participation and persistence within game culture. This emphasizes how community factors and individual factors have a reciprocal relationship, and how community factors can help foster resiliency and positive mindsets that affect performance, particularly for the most vulnerable (Richard & Hoadley, 2015). In other words, our work and frameworks need to address the intersecting areas of sociocultural and individual factors that impact awareness of these spaces, opportunities to participate and expectations once they are there.

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Designing Science Lessons With a Focus on the Demands of the Language of Science

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Introduction

My current research seeks to understand the process undertaken by science teachers in designing and implementing lessons in response to the language demands of science learning. It constitutes a progressive step towards a larger research program that aims to:

- develop principles and/or framework for guiding the design of science lessons with an explicit focus on the demands of scientific language
- inform the design of professional development programmes for fostering sustainable development of science teachers' competencies in identifying and addressing the language demands of science

Research impetus

The role of language in science learning and teaching has been a focus of science education research for over three decades. This rich body of research has led to the insight that learning the language of science is constitutive of learning science: simultaneously with participating in classroom activities and conversations, describing observations and developing conceptual understanding, students must begin to appropriate the language of science. To support students in appropriating and employing the language of science effectively, teachers need to recognize what these language demands are and be able to integrate and implement strategies, activities and tasks into their lessons that address these demands in an explicit and systematic way.

Theoretical framework

My research is underpinned by a theoretical framework that integrates both the socioconstructivist and sociosemiotic perspectives of learning (Seah, Clarke & Hart, 2011). This integrated framework emphasizes the role of language as providing cultural, cognitive and semiotic tools for the construction and representation of scientific knowledge. It also provides theoretical support for our assumption that learning the language of school science and learning the scientific content mutually reinforce and support each other.

Methods used

Informed by design-based research, my current project is characterized by the following features: (i) working in close partnership with practitioners; (ii) co-designing pedagogical interventions based on existing established principles for designing relevant learning environments and tasks; (iii) using a variety of methods to evaluate; (iv) with the goals of both generating and refining design principles and (v) having a practical impact on practice. The variety of data collected include: (1) video recording of teachers' interactions in classrooms; (2) video recording of student group interactions; (3) video recordings and notes of the weekly meetings with teacher participants; (4) video recording of teacher interviews; (5) lesson materials and student artefacts; and (6) student survey.

Current research progress and plans for moving forward

Earlier projects conducted in a primary school provided baseline understandings of the linguistic challenges encountered by students and the perceptions and issues that science teachers grappled with in developing and enacting lessons with a language focus (Seah, 2015a, b). Though situated within a different context of a secondary school, the insights gained from the earlier projects have been invaluable in informing the current project.

The richness of the data collected so far in the current project, which I am in the midst of analyzing, will further illuminate the process in which science teachers select, integrate, adapt and implement existing and newly co-developed pedagogical practices and resources in their own lessons. Such an understanding will help specify what skills and knowledge teachers would need in order to effectively design and execute science lessons with a focus on addressing the language demands. In addition to the teachers' perspective, the students' outcomes in term of conceptual learning will also be of interest as that could also shape the future direction of the research.

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Advancing Surgical Education: What Does It Mean to Think Like a Surgeon?

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Introduction

Surgical education, and medical education in general, is a field in which there has been a recent surge in interest and efforts to study. This has in part been in response to changing requirements for the training of residents and medical students. In the field of surgery, emphasis has been placed on attempting to understand what kind of learning happens in the five to seven years that a physician-in-training spends as a surgical resident, and how these learners develop into proficient and competent surgeons that are able to practice independently and train the next generation. In my role as a surgical education researcher, two primary questions that drive my work are: 1) What does it mean to think like a surgeon, and 2) How do physicians-in-training learn to be surgeons? The following project descriptions illustrate some of the work I have collaborated with faculty surgeons on related to these questions.

Samples of current projects

Medical student education

Virtual surgical patient cases

Simulations and virtual environments are being increasingly utilized as resources in medical education to allow students to engage in problem-based learning. This approach requires learners to actively consider a patient's medical issues and independently make decisions about the best course of treatment. A situated cognition perspective emphasizes the importance of developing the skills of and learning to think like more expert members of a culture, ideally in settings that are relevant to the way these practices will be used as part of learners' lives and work (Brown, Collins, & Duguid, 1989; Robbins & Aydede, 2009). By supporting students to think like practicing physicians, virtual patient scenarios can be successful at helping students learn clinical reasoning and decision-making skills used by practitioners.

One such platform to engage in simulated patient scenarios is the Virtual Surgical Patient Cases (VSPC) software, developed by discourse.[LLC] In this program, medical students take on the primary role of practitioner in a setting that allows for feedback and low-risk failure that can aid in the learning process (Yang et al., 2013). One line of my work seeks to understand how medical students use Virtual Surgical Patient Cases as a low-risk environment for learning that simulates decisions that they will have to make in practice and how they respond to the immediate feedback provided. Individualized practice through attempting something on one's own and struggling through the process allows learners to practice the skills used by practitioners in an environment that is safe for making mistakes. However, additional work is needed that investigates how best to integrate these platforms into the surgical curriculum (Cook, Erwin, & Triola, 2010), particularly to enhance the experiences of medical students. My studies related to this topic have and will continue to utilize log file analysis, focus groups, interviews, and observations as well as performance metrics from the cases in terms of the completeness and correctness of treatment decisions. In this way both qualitative and quantitative analyses can be combined to better understand how students are interacting with the virtual patient cases and which surgical thinking and decision making skills are being learned and demonstrated.

Resident education

Trauma simulation program

There are 30 million trauma patients a year, and trauma is the leading cause of death in patients younger than 44. Studies estimate that 10% of trauma deaths are related to preventable errors. The majority of these errors occur during the trauma initial assessment. Because of the complex, time-critical, and high-risk nature of trauma initial assessment, errors of non-technical skill – decision-making, communication, teamwork, and stress management – predominate over errors of technical skill (Vioque et al., 2014). Development of these non-technical skills during trauma education is essential to improve trauma outcomes.

To address this issue, professional medical practice can be approached from the perspective of epistemic frame theory (Shaffer et al., 2009). This theory suggests that professionals rely on domain-specific skills and knowledge to make and justify decisions. But complex thinking does not involve merely *having* a set of knowledge, skills, values, and ways of making decisions. Instead, the connections among the different elements of problem solving are critical. In trauma settings, these complex processes can be thought of as being distributed among the team members and can be examined through the ways in which team members communicate with each other to make decisions on how to proceed. Communication events and the relationships between these events are important for defining teamwork quality. However, what connections are important and how different networks of connections relate to trauma performance remain undefined.

Given that the relationships among communication events between the team members most certainly play a role in successful trauma initial assessment, an assessment tool is needed that can detect and quantify these relationships. Epistemic network analysis (ENA) is a tool that is able to statistically model these systematic connections in team communication and how they change over time (Shaffer et al., 2009). ENA has been successfully utilized to assess learning in a wide variety of contexts, including surgical education. In a study of operative simulation of hernia repair, for example, the relationship between operative planning and management decisions was associated with hernia repair quality, while independent versus assisted performance was not. Notably, it was the *integration* of these elements of planning and management of an operative assistant, not just their occurrence, which influenced the success of the simulated procedure and differentiated high and low performers (D'Angelo et al., Under Review). Similarly, ENA can be used to assess non-technical performance of trauma teams during simulated scenarios and describe more specifically what constitutes successful teamwork in terms of communication events taking place during initial assessment and resuscitation.

Our long-term goal is to develop an objective assessment utilizing ENA that allows us to measure the relationships among communication elements during trauma initial assessment scenarios. We hypothesize that ENA will be able to significantly discriminate between the communication events of trauma teams that have high and low global teamwork and overall performance scores in simulated trauma care. This will allow for evaluation of the communicative interactions that are important for improving trauma teamwork, which will then provide concrete targets for educational interventions and permit meaningful comparison across teams.

Future research plans

The problems addressed in my research relate to the bigger learning sciences theme of working to better understand how we teach people to think and perform like professionals. I employ a mixed-methods approach to my research in order to utilize both qualitative and quantitative techniques to better identify how learning takes place and how different educational interventions impact surgical performance and, in turn, patient outcomes. My future research plans include continued exploration of the role of simulation in surgical education for acquiring technical, decision-making, and interpersonal skills. In particular, I am interested in further exploring the role that simulation plays for acquiring skills before performing in the operating room and other practice settings. Finally, I plan to apply these perspectives to faculty development and learning of practicing surgeons.

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Children's Social and Emotional Development in Collaborative Learning

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My research examines how children develop socially and emotionally as they engage in joint cognitive efforts in collaborative learning. Surrounding this topic, I have developed three lines of research: 1) children's emergent leadership in collaborative problem solving; 2) the impact of instructional settings and peer interaction on children's behavioral and emotional engagement; and 3) the influence of technology, particularly table-top computers with large shared screens, on the social dynamic and students' collaboration in small groups.

Children's emergent leadership

Child leadership is a valuable construct for describing the dynamics of student interaction, and is different from several related constructs in cooperative group research, such as helping and peer tutoring (Miller, Sun, Wu, & Anderson, 2013). Although prior research has shown that children emerge as leaders spontaneously in collaborative learning groups (Li et al., 2007), it is not clear whether such emergent leadership can be sustained. To address this, I designed and conducted a large quasi-experimental study involving 252 fifth-grade students from Mideast China. Effectiveness of children's attempted leadership behavior in the cooperative problem-solving activity was found to be significantly higher among those who had previously participated in collaborative reasoning discussions, despite the fact that children were shuffled into new groups and worked on very different collaborative activities. This study showed that participating in peer-led collaborative discussions gave children the chance to observe, practice and internalize features of effective leadership, which enabled them to use leadership skills appropriately in a completely new task with a different group of children.

Children's engagement and affect in collaborative learning

In my dissertation, I examined how children's behavioral and emotional engagement in learning and understanding of key concepts were influenced by the instructional settings they were placed into, and how their evolving collaborative interactions were shaped by the complex social system formed by friendship, social status, talkativeness and ethnicity. Drawn upon a large intervention project where 24 fifth grade classrooms of mainly African American and Latino children from low-income homes participated, I examined children's learning through analyzing data from six weeks of observations using both qualitative and quantitative methods. For example, to examine children's real time engagement in learning, I developed coding schemes of children's on/off-task behavior and negative/positive affect from the video recordings of classroom interactions. By investigating the proximal effect of children's social interactions on their changing behavioral and affect in collaborative learning and direct instruction, the study advanced understanding of the processes by which children develop socially and come to experience positive emotional states during small group interaction.

Collaboration through multi-touch screens

Beyond studying collaborative learning in K-12 settings, I am also interested in the cognitive and social benefits of collaboration in higher education in the Science, Technology, Engineering, and Mathematics (STEM) fields as well as teacher education programs. In a three-year Cyberlearning project funded by the National Science Foundation, I contributed to a collaborative project in Education and Engineering to examine how engineering undergraduates solve problems through collective sketching on multi-touch devices. Extending this work, I introduced technology supported collaborative learning into the teacher education program at the University of Montana, and study in particular, how multi-touch table top computers with large shared screens change the social dynamic and students' participation in small group activities.

Looking forward, I plan to continue my research examining how learning and social emotional development occur in collaborative learning contexts in classrooms. Through this work, I hope to transform theoretical understandings into intervention programs. I am also actively seeking collaboration with colleagues from Education as well as the STEM fields in bringing more collaborative learning into undergraduate courses. This research agenda will, I hope, make a worthwhile contribution to learning sciences and a timely contribution to education broadly, as collaboration has been highlighted as an essential 21st century skill.

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Flexibility and Adaptability of Collaborative Learning Scaffolds

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Theoretical framework

Evidence-based reasoning skills are increasingly needed in professional activity. Especially these skills are needed in teaching when lessons are planned. In order to base their decisions regarding the lesson planning on scientific evidence, teachers need evidence-based reasoning skills. A well-arranged collaborative learning environment seems to be the perfect place to learn these skills as reasoning is often connected to dialog and argumentation. In short, teachers need evidence based reasoning skills to argue for their choices in their lessons planning when confronted with criticism from their colleagues, parents or supervisors. A large amount of studies has been focused on how collaborating learners can be supported with collaborative learning scaffolds for acquiring domain-specific knowledge and domain-general skills. For instance, computer-supported collaboration scripts are scaffolds that structure the collaborative learning process by sequencing and distributing activities that must be fulfilled by the learners and herewith support the acquisition of knowledge and skills (Vogel, Wecker, Kollar, & Fischer, accepted). Particularly, computer-supported collaboration scripts were applied with the target to enhance learners' argumentation and reasoning skills in different domains (e.g., social science: Weinberger, Stegmann, & Fischer, 2010; mathematics: Vogel et al., 2013)

When scaffolds like computer-supported collaboration scripts are designed by researchers, many assumptions are made on which activities should be induced by the scaffolds in order to enhance the collaborative learning process and the acquisition of knowledge and skills. Recently published theories are concerned with the questions how learning with collaborative learning scaffolds works and which activities are most beneficial for learning. The Script Theory of Guidance (SToG) delivers a framework for activities within computer-supported collaboration scripts that can be categorized in three levels of increasing specificity, namely the play-, scene-, and scriptlet-level. (Fischer, Kollar, Stegmann, & Wecker, 2013). The ICAP (Interactive > Constructive > Active > Passive) model is rather concerned with the categorization of specific activities within collaborative learning into interactive, constructive, active or passive activities, postulating that the interactive activities are most beneficial for learning (Chi & Wiley, 2014). Yet, the relation between the activities actually used in the learning processes and the learning outcomes are often not focused by studies about the effect of collaborative learning scaffolds. Therefore, one has to believe that the design of the collaborative learning scaffold is a good predictor for what is going on in the learning process. But this cannot be granted (Kirschner, Strijbos, Kreijns & Beers, 2004). Thus, it is necessary to focus on the assessment of the activities learners are actually using when supported by a collaborative learning scaffold (e.g., Vogel et al., 2013).

Furthermore, criticism about providing too much and too rigid structure to the learners by supporting them with collaborative learning scaffolds states that learners might be inhibited in using their own, maybe also beneficial collaborative learning activities), and too much structure provided by the collaborative learning scaffolds might lead to motivational problems. Thus, adapting the collaborative learning scaffolds to the learners needs should be more effective for the acquisition of knowledge and skills. The adaption can either be done by gradually fading out the collaborative learning scaffold or by making a collaborative learning scaffold automatically adaptive to the quality of the input of the learners. While the first method would still have a fixed structure (the fading is not necessarily adaptive to the learners needs), the second method would need a high investment regarding the use of technology and the costs. Therefore, making the collaborative learning scaffolds adaptable for the learners themselves to their perceived needs seems to be a good compromise between the affordances of scaffolds that can be adapted to the learners' needs and a solution that has a reasonable amount of investment regarding technology and costs. Yet, it has to be taken into account that the ideal adaption of learning support needs self-regulation skills and metacognitive strategies (Järvelä and Hadwin, 2013). While good self-regulators might benefit from adaptable support, less good self-regulators might be overwhelmed by the task to adapt the collaborative learning scaffolds. As a consequence, only good self-regulators would be supported with adaptable support.

Methods used

In my research so far I did a meta-analysis to find out the effect of computer supported collaboration scripts as a specific type of collaborative learning scaffolds on domain-specific and domain-general learning outcomes. I found a small effect on domain-specific learning outcomes and a large effect on domain-general learning outcomes. Yet, due to the lacking focus on learning processes in the primary studies, it was hard to come up with a conclusion about which kind of learning activities would be responsible for the learning outcomes.

Therefore I had a closer look on learning processes in an experimental research project about the effect of a collaboration script on mathematical argumentation skills. Here I found that especially self-generated interactive argumentation mediated the effect of the collaboration script on the argumentation skills. In the upcoming studies I will also use meta-analyses and experimental studies to find out more about learning activities used in the context of collaborative learning scaffolds and their specific effect on learning.

Plans for moving forward

The theoretical framework and the research done so far, leads to three overarching research questions that are concerned with the topic which activities work best in collaborative learning and how can these activities best be induced during collaborative learning:

RQ 1: In empirical research, which types of collaborative activities that are supported by collaborative learning scaffolds can be found to be actually used during the learning process and what is the impact of these activities on learning?

RQ 2: What is the effect of a highly adaptable collaborative learning scaffold compared to a rigid and fixed collaborative learning scaffold on learning evidence based reasoning skills?

RQ 3: How do learners make use of meta-cognitive and self-regulation strategies to adapt the collaborative learning scaffolds to their own needs and how can good self-regulators be distinguished from less good ones.

These research questions will be tackled by three studies that will be conducted in the near future.

In the first study a meta-analysis will be created with the focus on collaborative activities that are induced by collaborative learning scaffolds during the learning process and their impact on learning outcomes. Three relevant databases (ERIC, SCOPUS, Web of Science) will be searched with an appropriate search term. The found articles will be rated for their eligibility. After that the articles will be sorted by the collaborative activities that are used by the learners and categorized in top-down categories that are constituted by the theoretical approach of SToG and the ICAP model (Chi, 2009; Fischer et al., 2013) and the impact on learning.

The second study will be an empirical study about the effectiveness of differently flexible and adaptable collaborative learning scaffolds on teachers' learning of evidence based reasoning skills.

The third study will be an empirical study in which it will be explored how good learners and less good learners chose their own collaborative learning activities. With a qualitative approach the course of actions of the study 2 will be analyzed and evaluated. By this approach I hope to find the metacognitive and self-regulation skills that are necessary to choose beneficial collaborative learning activities. To distinguish good self-regulators from less good ones, a questionnaire for self-regulated learning readiness will be tested and analyzed.

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Learning Mathematics Through Designed Digital Experiences

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I claim that using video games is the way Euclid would have taught basic mathematics had that technology been around in ancient Greece (Devlin, 2011, p. 47).

Introduction

My research, broadly speaking, focuses on designing, building, and evaluating digital media products to support mathematics learning. By *digital media*, I mean technology-based innovations in the form of software, applications, e-books, and games. By *mathematics learning*, I mean informal and voluntary mathematics learning. Most recently, I designed and built a game for my dissertation, *Rolly's Adventure*, that has an underlying structure that models the behavior of fractions when they are multiplied, although the game never explicitly reveals this to the players. Rather, the players manipulate concrete (digital) representations of fractions that increase in complexity over the trajectory of the game, and are introduced to additional game features that align with mathematical features of fractions. Through gameplay, players uncover these systematic and underlying patterns. I have come to define this type of designed digital experience as a *provocative object*.

Provocative objects push against the trend of offering a smooth trajectory of learning by intentionally omitting traditionally offered mathematical resources. These gaps require players to engage in mathematical reasoning by hypothesizing, testing, and revising hypotheses, both within each puzzle in the object, and across the full trajectory of play. For example, *Rolly's Adventure* was designed to simulate the multiplication of fractions, but does so with novel concrete representations and digital interactions such that players are never told that the game is about fractions. In particular, *Rolly's Adventure* never mentions multiplication (in verbal, visual, or symbolic methods), and doesn't even hint at the idea that there's a mathematical operation occurring when players interact with the game. Players must reason within and across the game-based tasks to develop and nuance a hypothesis that engaging with the game results in multiplicative operations on fractions. In other words: provocative objects intentionally omit mathematical information traditionally deemed necessary to learning, and requires the player to both discover that mathematical information is missing, and then reason through that missing information with hypothesis-testing cycles.

Theoretical framework

My research is based upon an embodied constructivist perspective that emerged from my previous research with Dr. Amy Ellis (e.g., Ellis et al., 2015), and Drs. Mitch Nathan and Martha Alibali (e.g., Williams-Pierce et al., 2012). In short, individuals learn through experience, and they both learn and demonstrate that learning in part through physical actions and gestures. My design approach focuses on grounding mathematical learning and notation directly in experience through visual representation, interaction, and feedback, but during evaluation I do not assume that player-learners actually experienced what I intended. Instead, I seek to understand what their individual experiences were, and how varying mathematical outcomes resulted from those lived experiences.

Methods

In this section, I distinguish between my design methodology – that is, the process of designing *Rolly's Adventure*, and future products – and my research methodology – that is, how I examine and explore the success or failure of my designs on mathematics learning. My *design methodology* was guided by a previously developed design framework (Williams-Pierce, 2015) that synthesized the work of Brousseau (a mathematics educator; 1997) and Salen and Zimmerman (game designers and scholars; 2003). While using that synthesis as the broad guiding strokes for my design, much of the details within were informed by Gee's (2003, 2005) principles of learning, and leading researchers in fractions learning (Hackenberg, 2010; Lobato & Ellis, 2010; Steffe & Olive, 2010; Tzur, 1999).

My *research methodology* focuses on evaluating the mathematical learning and individual experiences of participants, by conducting semistructured interviews designed to evaluate background fractions knowledge, having them play through my products (at this time, *Rolly's Adventure*), then conducting another semistructured interview parallel to – but more difficult than – the first. The sessions are videotaped, and the playthroughs are screen captured so I can sync the video data and the screen capture data to gain a broader view of their gameplay experience. I then transcribe the interview and gameplay data, including physical gestures and digital actions, and analyze the transcripts through an emergent lens, guided (like my design methodology) by both my synthesized design framework and research by games scholars and fractions researchers. My dissertation data was collected and analyzed using this methodology with middle school students (5 dyads and 6 individuals).

Current findings

My current (preliminary) findings with *Rolly's Adventure* indicate, unsurprisingly, that both previous fractions experience and gameplay experience influenced participants' play and learning. In particular, it appears that participants who expect a coherent game experience, and who are able and willing to cross representational boundaries in their mathematics understanding, tended to be more successful in both playing and learning. Participants who were reliant upon the concrete representations – and struggled with symbolic representation in their pre- and post-interviews – dismissed the mathematical notation that appeared as the puzzles became more complex, and struggled to successfully complete the game based solely on the concrete representations and visual feedback. Participants who were particularly advanced in mathematics, and overly reliant upon mathematical notation in their pre- and post-interviews, struggled differently, failing to make sense of the concrete representations and visual feedback at the beginning of the game. In addition, regardless of their mathematical prowess, participants with less game experience viewed each puzzle within the game separately, so instead of developing, testing, and revising a hypothesis throughout the experience (as more advanced game-players did), they would develop, test, and revise a new hypothesis for each puzzle, leading to a less nuanced view of the game – and underlying mathematical content – as a whole.

Future research

My future research will continue to build upon *Rolly's Adventure*, and nuance the definition of *provocative object*. In particular, I plan on expanding the participant pool using *Rolly's Adventure* to include mathematics graduate students and professors, following the same protocol as I used previously with middle school students. In addition, I plan to implement *Rolly's Adventure* in early elementary classrooms, as a whole class event that serves as the first introduction to fractions, and co-designing (with teachers) a curricular bridge from the game to the traditional fractions content.

As this research continues to evaluate the influence of *Rolly's Adventure* on fractions learning, I am continuing to develop products that refine the definition of *provocative object*. In particular, I am designing an interactive e-book version of *Rolly's Adventure* that is intended to be explored by parents and their children. In addition, I have formed a multi-university team that includes experts in mathematics, equity, STEM, and connected learning to explore the potential of *Scratch* as a provocative object for learning mathematical practices.

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Doctoral Consortium

ICLS 2016 Doctoral Consortium Workshop

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Introduction

The ICLS 2016 Doctoral Consortium Workshop, designed to support the growth of young talents in the field of the Learning Sciences, provides an opportunity for advanced Ph.D. students to share their dissertation research with their peers and a panel of faculty serving as mentors. Participants will engage in collaborative inquiry and scholarly discourse to improve their dissertation work and to advance their understanding of the field. To benefit from the Doctoral Consortium Workshop, applicants should be advanced graduate students, and be at a stage in their dissertation research where the participants and mentors may be of help in shaping and framing the research and analysis activities.

Objectives and design

- provide an opportunity for participants to reflect on their dissertation research and to highlight problems/issues for further discussion and inquiry;
- provide a setting for participants to contribute ideas as well as to receive feedback and guidance on their current research;
- provide a forum for discussing theoretical and methodological issues of central importance to the Learning Sciences;
- develop a supportive community of scholars in the Learning Sciences across countries and continents;
- collaborate and draw upon literature across countries and institutions;
- contribute to the conference experience of participating students through interaction with other participants and consortium faculty; and
- support young researchers in their effort to enter the Learning Sciences research community.

Doctoral Consortium Workshop activities are organized around small-group interactions. During the workshop, participants will first present their research briefly to familiarize each other with their dissertation project and highlight specific aspects they would like to have further discussion on. These may include specific problems for which the student is seeking advice; intriguing issues and tensions for research generally; methodological problems that other Ph.D. students are also likely to be confronting, or issues that have the potential of stimulating discussions of theoretical and methodological significance. Then, based on the common issues and themes identified (theoretical models, research design and questions, pedagogy and technology, data collection, methods of analysis etc.) participants will form small groups supported by an expert mentor, to engage in further inquiry and discussion. Participants will work on the various problems and issues identified making reference to their own dissertation project and the broader field of the Learning Sciences. As well, they also have the opportunity to raise questions, provide suggestions, and help each other to improve their dissertation research. After the small group interactions, participants will report their progress and new questions to the whole group. Plans for further joint activity will be discussed as well.

Selection process

We received 51 applications from Asia, Europe, the USA and Australia and accepted 13. Two independent reviewers evaluated each proposal in terms of novelty, quality and timing, and the committee further considered the reviews.

Participants

Selected participants, their institution, country and title of their submission are below:

- Uzi Zevik Brami, Ben-Gurion University of the Negev
- Julia Erdmann, Ruhr-Universität Bochum
- Paul Flynn, The National University of Ireland

- Jonathan Halls, University of Nottingham
- Lisa Hardy, University of California at Davis
- Darlene Judson, University at Albany, SUNY
- Liang Leming, University of Hong Kong
- Nicole D. Martin, University of Wisconsin at Madison
- Hanelore Montrieux, Ghent University
- Raha Moussavi, Worcester Polytechnic Institute
- Alisha Portolese, University of Sydney
- Andi M. Rehak, Indiana University at Bloomington
- Charissa Tansomboom, University of California at Berkeley

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Fostering a Disciplinary Stance in Higher Education History Learning

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There is a growing interest in understanding how epistemologies develop through classroom interactions. Still, our understanding of these processes is rather limited. Understanding such processes in the context of higher education seems key, because academic beliefs are said to develop and become more dominant than general epistemic beliefs as learners advance in formal education (Muis, Bendixen, & Haerle, 2006). We refer to such discipline-specific beliefs, to an understanding of the forms of knowledge and of the procedures for knowing that are valued in a community, as a disciplinary stance (Tabak & Reiser, 2008). Therefore, we set out to investigate how a disciplinary stance develops through epistemic socialization in higher education. Specifically, we look at how learners interpret and take up the messages that written and oral texts in history courses communicate about what knowledge is valued and of how it is constructed. As an initial step, we employed a classroom ethnography in an introductory undergraduate history course, conducting observations and interviews to investigate how epistemic messages about the nature of historical inquiry were communicated in the course, and how the students interpreted these messages.

Preliminary analysis of lectures, recitation sessions, and materials revealed that the course texts communicated two main epistemic messages. The first message concerned *Perspective*, that is, the perspective of historians in their writings about history. For example, one scholar might examine the past with the intention of identifying power relationships, while another might interpret the same patterns as a function of economic incentives. The second message concerned *Context*, which refers to the principle that historical inquiry needs to take a wide gaze to understand events. Two of the five students that we interviewed seemed to adopt at least one of the core epistemic messages in the course. For example, one of these students reported that an article in the course's assigned reading led him to reflect on how historians' perspectives are justified in light of their available conceptions at the time of writing. This student's interpretation corresponds with the epistemic message of *Perspective*. What seemed to enable these students to take up the core epistemic messages of the course was an interaction between their persistence in reading the course texts, their ability to relate the texts to the historical framing presented in the lectures, and their adoption of the interpretive moves modeled by the instructors in recitation sessions.

These findings highlighted the role of secondary texts in the undergraduate history curriculum, and illustrated that formal education has the potential to cultivate students' historical reasoning. Consequently, in this research we are motivated to investigate how to increase this potential through a deliberate instructional focus on disciplinary stance. Drawing on design-based research methods, we will interleave non-intervention observational studies of undergraduate introductory history courses, with design of material, computational and social tools to support historical reasoning around secondary texts, with observational studies of courses that make use of these tools. The non-intervention observational studies will try to understand what features in the instruction and learning of secondary texts are common in undergraduate history courses. Literature of historical reasoning around primary sources (Wineburg, Martin, & Monte-Sano, 2014) will be juxtaposed with observational data to articulate an initial model of historical reasoning around secondary sources. We will then validate the initial model with expert historians and history instructors. The intervention will build on the elaborated version of the model to design supports for historical reasoning around secondary texts.

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Acknowledgments

Improving Conceptual Knowledge Acquisition in Online Courses by Adding Collaborative Learning Elements

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Online education often focuses on individual learning and provides limited opportunities for social interaction and collaborative learning. Implementing collaborative learning in online courses successfully is a major challenge. On the one hand, research on collaboration in large online courses suggests that social interaction in form of small group discussions may substantially improve learning in online courses (e.g. Rosé, Goldman, Zoltners, Scherer & Resnick, 2015). On the other hand, learning collaboratively in small groups may not always be ahead of learning individually (e.g. Slavin, 1983). Whether collaborative learning is implemented successfully may depend on the type of knowledge that is targeted. Collaborative learning elements seem especially suitable for gaining conceptual knowledge. In collaborative learning settings learners are encouraged to verbalize their knowledge gaps, to discuss different points of view (Herrmann & Kienle 2008), to engage in mutual elaboration, and thus to jointly extend their knowledge (Chi, 2009). I hypothesize that for conceptual knowledge construction, learning collaboratively in small groups may be more effective than learning individually. The findings of Mullins Rummel & Spada (2011) support this assumption.

To test my hypothesis, I conducted two experimental studies investigating the effects of learning mode (collaborative vs. individual) on conceptual knowledge construction in an online-learning course on psychological principles of computer mediated communication, using a between-subjects design. A knowledge test measured students' learning gain. Analyses did not find significant effects of the conditions in *Study 1* nor in *Study 2*.

This result was surprising. However, several possible reasons for this outcome could be identified. First, the course suffered from typical problems in online courses namely a *high drop-out-ra*te, *low individual accountability* and *low commitment*. These problems can lead to groups with an insufficient number of active participants. Second, did students learning collaboratively actually collaborate well? Collaborative learning usually needs support (e.g. in form of scripts) to be successful. However, providing this support may confound the comparison between individual and collaborative learning. Third, the definition of conceptual knowledge in my research is based on a common differentiation between knowledge types in research on knowledge acquisition: that between conceptual and procedural knowledge. This distinction has mostly been made with mathematical contents and on well structured problems (e.g. Mullins, Rummel & Spada, 2011, Rittle-Johnson & Alibali, 2001). However the problems in the knowledge domain I worked with (social sciences) are ill-structured. This poses problems for constructing tasks for acquiring conceptual knowledge as well as for evaluation of knowledge gain as correct solutions can be manifold. Hence the definition of conceptual knowledge might not be valid for the learning content I used in my studies and thus explain why the results of my studies differ from other research on conceptual knowledge acquisition in more well-structured knowledge domains (e.g. Mullins, Rummel & Spada, 2011, Rittle-Johnson & Alibali, 2001).

In further research I plan to investigate in detail the nature of conceptual knowledge in social sciences, as this will be important for further research investigating conceptual knowledge acquisition.

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Exploring the History of Education: Designing for Transition Into Undergraduate Initial Teacher Education and Towards Professionalism

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Goals of the research

This research project is concerned with the transition of new entrants to third level education and towards professionalism, particularly within the domain of undergraduate initial teacher education (ITE). Contextualised by an undergraduate mathematics and education programme, it seeks to develop pre-service teachers' emerging professional identities, as members of a pre-professional community of practice (Lave & Wenger, 1991), evidenced through a designed collaborative engagement with the history of education.

Background of project

The project focuses on the continuum of secondary school teaching which has long been beset with concerns regarding the isolation of teachers in their classrooms and how that, established culture, perpetuates the perception of a teacher as an individual rather than members of a collaborative community (European Commission, 2014). Efforts to ameliorate this issue have largely focused on in-service teachers, however there is a dearth of work in relation to developing such communities within ITE. Of particular interest therefore, are new entrants to undergraduate ITE who have just left the secondary school system. These recent observants of in-service teachers also face the concomitant challenges of life at third level education.

Methodology

This study employs design-based research (DBR, Barab & Squire, 2004) with the aim of iteratively developing a real-world relevant design methodology that may serve to help new entrants to undergraduate ITE transition into third level education and towards professionalism. The DBR intervention is a twelve-week non-elective module on the History and Structure of the Irish Education System. All participants (N=35) were new entrants to ITE and to this programme. Module time was split between historical content and designed collaborative activities. Data were collected through: focus groups, questionnaires, ethnographical observations, and reflective essays the participants' constructed as a website and working portfolio. During the first design cycle, in an effort to establish four distinct learning communities (Lenning & Ebbers, 1999) within the cohort, representative of an emergent Community of Practice (CoP, Lave & Wenger, 1991), a CSCL environment was developed to underpin the design model. However restrictions of the CSCL to a Virtual Leaning Environment (VLE) and a single platform output stifled the development of a CoP. A second design cycle was administered including the reduction of group numbers from four to three, streamlining of historical content and a relocation of the CSCL environment to the habitual communication spaces of the incoming students including a shared online website.

Current status

An analysis of the second design cycle has concluded that the design model has responded to the initial aim of the research. A third design cycle in September 2016 is feasible, however, whether or not there is a need to carry out this research is a topic for discussion at the ICLS 2016 Doctoral Consortium. This discussion may be primarily concerned with exploring the concept of what represents the equivalence of data saturation in a DBR study.

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Acknowledgments

Young Children Teleological Explanations for Natural Phenomena: Assessment Methods and Pedagogical Approaches

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My research focuses on children's reasoning about the natural world and how they can be helped to understand it scientifically rather than teleologically. Children, aged 4- to 8-years-old, are often considered to reason teleologically about the natural world: believing that an entity or event exists for a specific purpose (Kampourakis, 2014; Kelemen, 1999a). For example, night time is a signal to go to sleep, rainbows are for finding treasure or snow exists for children to make snowmen. A review of the literature (e.g., Kampourakis, Palaiokrassa, Papadopoulou, Pavlidi, & Argyropoulou, 2012; Kelemen, 1999b, 1999c; Ojalehto, Waxman, & Medin, 2013) suggests there are three areas which may have influenced the assessment of children teleological explanations and could have led to an overestimation of its prevalence. 1) Question wording, previous work has used questions with the generic stem *what is X for?* (e.g. Kelemen, 1999b), which could be considered teleologically-leading, by suggest that X is for something, that it has a teleological rationale. 2) Topic selection, some projects have used two or three topics of Natural Phenomena to propose that children reason teleologically about the whole category. However, the small number of topics used may not adequately represent the entire ontological category. 3) Concept construction, teleological explanations often refers to the construct of design-teleology (Kampourakis et al., 2012; Kelemen, 1999a) which is the belief that an entity has been created for a specific purpose (e.g. in the case *snow is for making snowmen* children actually believe that snow has been designed for the sole purpose of making snowmen). An alternative explanation of their responses is that children do not advocate this design-teleology stance but instead follow relational-teleology (based upon, Ojalehto et al., 2013) which refers to the way a child may relate the topic to an activity they use it for. Therefore, there is a distinction between the traditional design-teleology, snow is *for* making snowmen, and the more realistic relational-teleology, snow can be *used* to make snowmen. There is a clear difference between these two types of responses, with the latter proposing perhaps less of a developmental problem that the former.

Study One investigated the way in which assessment of teleological reasoning can be affected by the wording of questions and the selection of the topics. Furthermore, their teleological explanations were analysed to investigate the type of teleology espoused. The findings suggest that children's propensity to provide teleological explanations may have been somewhat overestimated in the research literature; indicating that the current view of children's teleological reasoning is not sufficiently nuanced. Children may be able to begin to reason scientifically about Natural Phenomena from a younger age than previously suggested.

The goal of Study Two is to develop an intervention that limits children's tendencies to provide teleological explanations for Natural Phenomena, by improving their ability to recognise if explanations for Natural Phenomena are appropriate (causal) or inappropriate (teleological). Therefore, enabling children to judge any future explantations with which they are presented. Study Two uses an experimental design to test the effectivity of the intervention. The intervention consists of four cognitive acceleration sessions that allow 6- and 7-year-old children to explore their, and others', ideas about Natural Phenomena. These sessions are discursive, grounded in dialogical teaching and argumentation, and aim to encourage a co-construction of purpose in nature. Pre-/ post-tests will be used to track any change in children's ability to correctly judge appropriate/ inappropriate explanations, and to provide a rationale for their judgement. The study is currently ongoing.

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Computer Support for Group Learning of Physics Models

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Scientific reasoning, broadly, is model-based— it involves the construction and use of models to reason about natural phenomena. While scientific reasoning is often thought of as something done within or by an individual learner's mind, in practice reasoning has both social and material dimensions. From classrooms to laboratories, reasoning with conceptual models takes place in a landscape of material artifacts— chalkboards, computers, specialized equipment— as well as within a social setting in which conceptual models arise and take shape from the interactions between learners. My dissertation research is an investigation of the ways that small groups of university students enact model-based learning and reasoning in technologically mediated, collaborative environments. I draw primarily from prior work on models and models-based learning (Louca and Zacharia, 2012), theories of distributed and group cognition and learning, as well as from computer-supported collaborative learning.

My research takes place in the context of the PHoTOnICs project at UC Davis: a design-based research project with the aim of investigating these social and individual intersections of science learning through design of novel, iPad-based collaborative activities for group-based Physics classrooms. Our research setting is a "studio physics" course at UC Davis (Potter et al., 2014) that aims to keep students engaged in high-level conceptual reasoning. Two aspects of the course serve that goal: small group work for 5 hours/week, and material organized around a small set of physics models. My dissertation aims to investigate the relationship between the social and technical setting to the development of understandings of those central conceptual physics models. My research questions are in the nature of group interactional processes of reasoning with physics models, the relation between those processes and individual learning outcomes, and the relationship between features of the designed learning environment and the group processes it promotes.

To date, I have piloted and collected data on two collaborative, iPad-based "distributed designs" (White and Pea, 2011), in which local computer networks distribute resources for accomplishing a shared task across a group of learners. The first design, "Making Waves," is an iPad application that simulates the motions of a set of individual mass-spring oscillators lined up along the x-axis. The application and local network distribute control of these oscillators across the students, and the students are asked to coordinate the relative motions of their oscillators to produce a travelling wave. In the second design, "Fields and Forces," the application distributes control of the positions and values of electric charges, and the students are asked to make predictions of the forces on each individual charge in the collective configuration. I have collected multiple rounds of data with the "Making Waves" design under two major iterations. An analysis of the first round of collected data was presented at CSCL 2015, and argued that the individual students in the group did not necessarily understand their activity similarly even when they appeared to come to a consensus. A second analysis (accepted to ICLS 2016 as a full paper) attempted to better characterize these differences in understandings, as well as to describe how they evolved as students interacted with one another. Building on this research in future cycles of research and design (Collins et. al, 2004), my dissertation aims to contribute to our understanding of the computer support of model-based science learning in small groups.

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Acknowledgements

Leveraging Teacher Noticing for Sustained Idea Improvement in Students' Knowledge Building Inquiry

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Research goals

Implementing inquiry-based collaborative learning models in classrooms for deep change requires the teacher to develop new roles and strategies to support student-driven thinking and interactions. The goal of this study is to advance theoretical and practicable understandings of teacher noticing for responsive decision making in support of students' sustained idea improvement in the context of collaborative knowledge building. My research leverages the construct of teacher noticing through the introduction of reflective teacher journals for an investigation of what teachers attend to and how they decide to respond in the context of a year-long grade 5 knowledge building inquiry of the human body.

Background

Knowledge building is a student-centered, inquiry approach mediated by collective knowledge spaces such as Knowledge Forum (Scardamalia & Bereiter, 2006). Students share collective responsibility for idea advancement through inquiry guided by their wonderings and emerging understandings. Existing research suggests the important dual role of the teacher as both a co-learner and responsive facilitator in the deepening process of knowledge building (Zhang, Hong, Morley, Scardamalia, & Teo, 2011). Research is needed to elaborate the teacher's role in ongoing idea improvement in such dynamic social contexts.

Teacher noticing has garnered recent attention, primarily in mathematics education research, as a construct for analyzing the interrelated skills of attending to students' thinking, interpreting students' understandings, and deciding how to respond based on those understandings (Jacobs, Lamb, & Philipp, 2010). As knowledge building is idea-centered by design, the construct of teacher noticing may provide an insightful framework for investigating teachers' decision making in supporting students' idea advancement as well as other facets of knowledge building the teacher may attend to including social norms and scientific practices.

Methodology

My research is design-based grounded in the natural setting of grade 5 knowledge building inquiry in four classes taught by two teachers. This study represents a year-long phase implementing weekly reflective journals based on the components of noticing (attending, interpreting, and deciding how to respond) kept by the teachers for each class in the context of ongoing knowledge building research in a multiyear project. Open coding is used to identify categories for qualitative analysis based on the teacher noticing framework (van Es & Sherin, 2008) to identify emergent themes in decision making. Quantitative analyses will be used to substantiate patterns.

Current status

Data collection and analysis is ongoing in the current school year. Initial analysis suggests a central theme of principle-based teacher noticing at the cutting-edge of collective knowledge: the teacher actively observes ongoing idea progress to develop a sense of new advances and challenges at the front edge of students' research and understanding in order to foster deeper inquiry actions. Beyond noticing of content-specific ideas, the teacher additionally traces emerging social and epistemic patterns of knowledge building to facilitate the establishment and adaptation of inquiry practices (e.g. inquiry cycles, norms of interaction).

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Co-evolutionary Dynamics Between Teacher Learning and Organizational Learning in the Process of ICT-enabled Pedagogical Innovations

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Background and research problem

Information and communication technology (ICT) has been adopted to transform pedagogy so that students' 21st century skills can be fostered. Such ICT-enabled pedagogical innovations (ICT-EPIs) often face the challenge of sustainability after the withdrawal of initial supports and resources. Recently, more and more learning scientists argue that the problem of implementing educational change is fundamentally a problem of learning at different levels of education systems (Stein & Coburn, 2008; Law, Yuen, & Fox, 2011). Teachers play a crucial role in implementing 21st century skills oriented pedagogy in classroom, and thus need to transform their traditional practices through continuous professional learning. To date, most studies highlight the important role of factors of individual level (e.g., teachers' belief, knowledge and experience) on learning and sustaining teachers' innovative practices over time, few of them shed light on the processes and mechanisms of how the factors of organizational level facilitate teachers' learning for sustainable change. This five-year longitudinal study aims to explore how the interactions between teacher learning and organizational learning might influence the learning outcomes of teachers in terms of sustainable innovative practices in the process of ICT-EPIs.

Theoretical framework

With the increasing attention on sustaining and scaling up innovative educational programs across different settings, learning scientists raised the research agenda to understand how the innovative program adapts to the local context in a co-evolutionary process in which teachers and school leaders need to "make continual coherent adjustments to the program" (Penuel, Fishman, Cheng, & Sabelli, 2011, p.331). Educational change theories from the perspective of complexity argue that innovation implementation by nature is the process of teacher learning to change by continuously practicing and adapting to the innovation, in tandem with the learning at organization level characterized by changing school vision, culture, resources and architecture for teacher learning. In lights of these theories, a conceptual framework comprising two levels of learning is constructed. At teacher level, learning takes place when teachers' practices conflict with their beliefs and knowledge. Good performance of students will also have positive effect on teachers' change. At organizational level architecture for learning (Stein & Coburn, 2008) influences teacher learning and is influenced by organizational knowledge and experiences in the process of organizational learning.

Methodology

In 2011, Hong Kong government launched a three-year e-learning pilot scheme, funding 21 ICT-EPIs projects involving 61 local schools. Four of these innovative projects were selected in a two-year follow-up project for the purpose of investigating their sustainability after the completion of the scheme in 2014. Case study is adopted to reveal the complex interactions between teacher and organizational level and their impact on teacher learning. Three strands of qualitative data will be collected: (1) interviews with principals, project coordinators and focal teachers; (2) observations of lessons delivered by focal teachers; and (3) collection of teaching plans of the focal teachers, as well as their students' works. Data (1) is used to uncover the changing and learning process of organization. Data (1) and (2) are analyzed to reveal the process of teacher learning in targeted schools as well as teacher changes in belief, knowledge and practice over time, while Data (3) serves as manifestation of the teacher learning outcome.

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Supporting Teachers to Develop a Holistic Conceptualization of Science Practices: A Framework to Transform Teachers' Classroom Practice and Improve Students' Understanding of Science Practices

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Science as practice has become a prominent perspective in science education emphasizing science as a process of understanding, evaluating, and representing the world around us (Lehrer & Schauble, 2015). Helping students learn science as practice requires significant changes from traditional science education, and we must provide teachers with appropriate support to implement this perspective (Reiser, 2013). Previous research has predominately focused on supporting science practices through instructional materials, but these materials must be complemented by *teachers'* understanding how to support students. Thus, I propose a framework (discussed below) that consists of four ways for *teachers* to support science practices that will offer new contributions by explicitly guiding teachers to understand the interdependencies and epistemic purposes of science practices. Tabak and Radinsky (2015) acknowledge that research on teaching is less frequent in learning sciences and call for exploration in this domain. My research will importantly address this gap by viewing teachers as learners and investigating how teacher learning of science practices influences student learning.

The goal of my research is to investigate how to support teachers to develop holistic conceptualizations of science practices that actively transform how they teach science and help students understand science practices. I break this goal into four connected components to: 1) refine a theoretical framework for a holistic conceptualization of science practices; 2) investigate how this framework can help teachers understand science practices as interdependent; 3) investigate how this understanding improves teachers' instructional support for science practices; and 4) investigate how teachers' instructional support influences students' understanding of practices. I have developed a framework proposing four support mechanisms for teachers to help students learn science practices: i. opportunities to engage in practices; ii. guidance for participating in practices; iii. guidance for why practices are important in science; and iv. guidance for how practices are interconnected. Previous research has found these supports to be beneficial for students, but supports have predominately been material-based tools, not guidance coming from *teachers*. I used this framework to preliminarily investigate teachers' current approaches to supporting science practices in the classroom and their understanding of science practices. My initial findings suggest that teachers may need additional guidance to 1) understand science practices as interconnected and 2) develop concrete teaching strategies that support students' leaning of science practices. These suggestions provide the basis for refining my framework and direct my dissertation work.

The participants will be middle school science teachers implementing design-based biology curricula. Teachers will participate in professional development as they implement curricula to develop their own understanding of science practices and teaching strategies for practices based on my framework. I will assess teachers' understanding of science practices through pre- and post-surveys and interviews to gain richer insights and further validate the survey measure. I will video-record teachers as they implement 8-10 week-long units, allowing me to capture how teachers support students throughout the process of generating scientific questions, conducting experiments, analyzing and interpreting data, and constructing and defending explanations to solve their design challenge. I will qualitatively and quantitatively analyze these classroom videos based on the four components of my framework to investigate how teachers' support for science practices changes over time as their understanding of science practices develops. I will use several student outcome measures to analyze effects of teachers' support on students' learning: pre- and post-tests of science practices understanding; final scientific arguments as measures of ability to synthesize science practices to explain phenomena. I anticipate that this study will help refine my framework to include concrete ways that teachers can support students' understanding of science practices and also to help develop professional training programs for teachers.

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Mobile Learning in Secondary Classes: The Use of Tablet Devices as a Learning Tool for Fostering Inquiry Learning and Self-Regulated Learning

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Introduction and goals

This study is embedded in the context of the digital age, in which technological progression - especially in educational matters - cannot be ignored, (Alvarez, Brown, & Nussbaum, 2011). Despite public debate on the introduction of tablet devices for educational purposes, research about the potential benefits of the usage of tablets in secondary education is still lacking. In contrast, research in higher education stresses the impact of these devices on motivation, achievement and collaboration (Alvarez, et al., 2011). Especially in science education, negative attitudes towards science are firmly connected with the way science is taught. 40% of the teachers interviewed reported not using technology; but believed that learner-centered, inquiry-based methods, compared to more deductive methods, could achieve an increase of interest and achievement in science (OECD, 2015). The aim of the research project is to investigate the added value the tablet for teaching and learning during science classes. We focus on the following research questions: What are the perceptions of students and teachers about the use of tablet devices? What is the impact of the application of these devices on motivation and knowledge construction? Does the introduction of tablets improve the inquiry skills and self-regulation of students? Finally, what is the impact of these devices on the teacher's role with regard to the learning process?

Methodology

Based on a design-based research approach, five consecutive studies are planned (three studies are already conducted). A mixed-method approach involving both qualitative and quantitative data is used.

Current status

A state-of-the-art study was conducted in the first secondary school in Belgium that has implemented tablet devices throughout the whole school and classroom organization. By using the Decomposed Theory of Planned Behaviour (Taylor & Todd, 1995), a three-wave longitudinal case study has been conducted in which teachers' (n = 83) as well as students' (n = 694) expectations and experiences towards the use of tablet devices were measured. Results show that attitudes of the respondents are generally positive but the appreciation tends to decrease after time. Additionally focus group interviews with teachers (n= 20) and students (n=40) show that teachers can be divided into two categories: innovative and instrumental teachers, which differ in both method of organizing courses, as well as in needs for professional development. Based on the state-of-the-art study, an intervention study with 140 students and their three natural science teachers has been conducted in the same iPadschool. The main focus lies on the role of teachers in a technology-enhanced inquiry learning. Three different macro scripts (Dillenbourg et al., 2009) are applied and compared in a quasi-experimental study. In the first condition, inquiry activities alternated between group level and class level. In the second condition, the group level dominated, as pupils had to work on inquiry tasks in pairs without plenary instruction. The third condition includes only plenary instruction with the tablet merely used as a 'book behind glass'. The respective impact of the different macro scripts on pupils' knowledge achievement, inquiry skills and perceived teacher support in the three setting were investigated. Our study demonstrates that inquiry-based activities require more than minimal guidance to remain effective. The role of the teacher cannot be ignored or replaced by technology. Based on these results, iterations will be implemented during March-May 2016 and March-May 2017.

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Iterative Design, Development, and Evaluation of Scaffolds for Data Interpretation Practices During Inquiry

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Developing explanations is a key inquiry practice in national science standards (NGSS Lead States, 2013) and essential for learning science content (McNeill & Krajcik, 2011). Toulmin's (1958) model of argumentation identifies three aspects of explanation: claims, evidence, and reasoning; others concur (Gotwals & Songer, 2009). Students often have difficulty with these tasks, such as not using appropriate data or providing reasoning (McNeill & Krajcik, 2011), and not linking data to claims or relying on theoretical arguments (Schunn & Anderson, 1999).

In supporting students on these key inquiry practices, scaffolding has been shown to lead to student improvement (McNeill & Krajcik, 2011). Additionally, prior work by our group (Sao Pedro et al., 2014) has shown that auto-scaffolding in Inq-ITS (Inquiry Intelligent Tutoring System; Gobert et al., 2013) can help students acquire two data collection inquiry skills and transfer them to a new science topic. These data provide a rationale for the work presented, namely, designing, developing, and evaluating a real-time scaffolding approach for the development of the inquiry practices for data interpretation and warranting claims, which, to us, underlie the argumentation practices necessary for communicating science findings, a key NGSS practice. Unpacking these practices can help us better understand, assess, and, in turn, scaffold them.

Specifically, this work addresses the: (1) design of scaffolds for data interpretation practices; (2) efficacy of scaffolds for supporting these practices, and (3) transfer of these practices from one science topic to another, with an end goal of incorporating into Inq-ITS real-time scaffolds for data interpretation. This work is iterative in nature in terms of its design, piloting, implementation, and classroom-based testing.

The first two studies focus on the design and evaluation of data interpretation scaffolds. For Study 1, scaffolds were designed based on common, *procedurally-oriented* difficulties students face when interpreting data. These, identified from literature, include: creating a claim that relates to the hypothesis, selecting appropriate data, creating a claim that reflects the data, and identifying if the claim supports the hypothesis. These scaffolds were pilot-tested one-on-one with middle school students to iteratively refine the scaffolds. Study 2 comprised of an assessment of students' performance on data interpretation with and without scaffolding. Study 3 focuses on assessing the transfer of data interpretation skills to a new topic. The goal for this study is to address how well students can interpret data after receiving the scaffolds as well as how well students can transfer these practices for data interpretation to a new topic.

This research builds on prior work on the nature of explanation (McNeill & Krajcik, 2011) as well as prior work on the assessment and scaffolding of science inquiry skills (Gobert et al, 2013; Sao Pedro et al., 2014). Conceptualizing the necessary sub-skills underlying explanation makes an important contribution because of its potential for developing the necessary scaffolds for supporting students. Our results to date indicate the potential of a scalable method for assessing and scaffolding various inquiry practices (Sao Pedro et al., 2014). This work extends our prior work to key inquiry practices involving explanation with the goal of assessing and scaffolding these in real-time in Inq-ITS; in doing so, we will have scaffolds for the full complement of inquiry practices outlined by the NGSS.

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Redesigning Problem-Based Learning in Medical Education: Contrasting Solutions to Improve Consolidation

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Goals of the research

Our goals are to better understand the mechanisms of how to support deep learning, transfer, mental model construction and conceptual change for medical education students, and to consequently improve the efficacy of the problem-based learning (PBL) design. We hypothesise that our new proposed design will be more efficient, improve student confidence in their understanding, and improve student understanding such that it is deeper, better connected, has changed more from initial preconceptions, and is more easily transferable to new situations. We aim to respond to the need for more observational studies in PBL with a close examination of the micro-level process mechanisms that might explain the learning that may (or may not) be occurring.

Background

Although PBL is widely used in medical education around the world, many of its design components are not adequately grounded in learning theory. While distinct from discovery learning (Hmelo-Silver, Duncan, & Chinn, 2007), PBL in certain ways can resemble a low guidance design, particularly in its latter closing phases as it is applied in our context, with concerns that it can resemble a passive "show-and-tell" of information. The reporting phase process of PBL can be extremely time consuming, and students can lack confidence in their learning. While students might *appear* to have mastered content with success on multiple-choice examinations, students may not have the deep understanding required for explanation and application to novel situations. The lack of theory and research for this critical phase is a significant blind sport in the literature, with major detriment to medical students, their tutors, and the community where they will eventually practice as doctors.

Combining low and high guidance can be powerful for deep learning and transfer, as shown with the productive failure (PF) design (Kapur, 2012). Like PBL, PF begins with a problem. Unlike PBL, PF follows with direct instruction and comparing and contrasting solutions, which efficiently consolidates understanding. Comparing and contrasting solutions can be effective feedback (Rittle-Johnson & Star, 2007), and incrementally differing examples can support schema construction (Gick & Patterson, 1992). This structured feedback could move the closing phase from a "show-and-tell" to a productive conceptual integration.

Methods

We are utilizing a design-based methodology with two main design cycles. Participants will be second year medical students and tutors at The University of Newcastle. The first iteration is in preparation. Four tutorial groups will trial our proposed Integrated Feedback method in two two-week clusters, such that within-group and between-group comparisons will be possible, and all participants will trial the new design eventually. During self-directed study, all groups will organise their research into concept maps, which will be brought to the PBL closing meeting. In the intervention, students' prepared maps will be used as a learning artifact for a grounded, tutor-facilitated compare and contrast exercise. The comparison group will aim to represent current practice, which typically involves students reporting what they found sequentially without explicit comparison and less directive instruction and feedback. The second iteration will be designed following lessons learned.

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Becoming a University Student: Tracing Living-Learning Community Students' Engagement in Big "D" Discourses

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Comprised of a group of students taking at least one course together who live in close proximity to each other, Living-Learning Communities (LLCs) are lauded for increasing student engagement, as measured by time and effort spent on "educationally purposeful" activities (Zhao & Kuh, 2004). Working at the intersection of learning sciences and higher education, I aim to build on the knowledge base of engagement in LLCs by employing a sociocultural perspective of learning as enculturation to investigate students' identity development during participation in a thematic LLC, Learn-Lead LLC (pseudonym). My exploratory dissertation seeks to address the following questions: (1) What is the nature of the Learn-Lead Discourse? (2) How do Learn-Lead students' identities develop across the school year? (3) What practices and features of Learn-Lead seem to support student transition into the university Discourse?

Learn-Lead activities are implicitly intended to enculturate students into the university Discourse by providing them with opportunities to legitimately peripherally participate. A sociocultural perspective of learning as enculturation (Lave & Wenger, 1991) views learning as a *process* by which individuals come to understand and take ownership of the practices of a Discourse. Through social activity Learn-Lead participants jointly negotiate what it means, and looks like, to be a member of the community. Engagement in the negotiated practices of Learn-Lead affords students' seeing themselves as members of the Learn-Lead community, and in most cases, as members of the broader university community. Students construct identities as members of a community through enactment of *big "D" Discourses* (Gee, 2008). Discourses are ways of being and doing that are specific to a particular social group. Enacting a Discourse requires distinctive use of language and ways of acting, interacting, believing, valuing, and using artifacts (Gee, 2011).

Prior analysis (Rehak, 2015) of classroom discourse in a beginning college program generated examples of students enacting, or bidding to enact, the university Discourse. Student practices included negotiating responsibilities in group work, critiquing textbook content, and investigating personal assumptions. The findings illuminated how curriculum design directly impacts the nature of student engagement, and, in some cases, can limit students' opportunities to legitimately peripherally participate. Particular objects supported students in drawing on their high school experiences in efforts to enact the university Discourse. *Boundary objects* (Star, 1998) can be conceived as bridging the activity of individuals as they transition from one Discourse to another. Examining the boundary objects that assist students in bridging their experiences can provide further insight into the enculturation process.

A *discursive psychology* (Jørgensen & Phillips, 2002) lens will be employed in efforts to understand the discursive practices of the Learn-Lead community. The *big "D" Discourse tool* (Gee, 2011) will be utilized to understand how beginning college students enact, or make attempts to enact, an identity as a member of Learn-Lead and of the university. Boundary objects that aid students' in bridging identities will be uncovered during the analysis process as well. This dissertation aims to further our understanding of how discursive practices are jointly developed and transformed in Discourses and how these discursive practices are enacted as learners transition from high school students to university students.

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Design of Automated Guidance to Support Student Agency and Knowledge Integration in Science Learning

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Immediate, personalized guidance can be beneficial in online learning, particularly when students make a directed effort to engage with guidance and revise their answers. Informed by the knowledge integration framework and established ideas about motivation and agency, this research explores useful and motivating forms of automated guidance for middle schoolers within the Web-Based Inquiry Science Environment (WISE; http://wise4.berkeley.edu) Thermodynamics unit using the NLP autoscoring tool c-raterML™. WISE is an online platform for science units that includes automated guidance steps where students' 2-3 sentence explanations are automatically scored, they receive personalized guidance corresponding to their score level, and are prompted to immediately revise their answer. NGSS standards emphasize iterative refinement as a key strategy for science learning. Guidance based on the knowledge integration (KI) framework for science learning, which is used in the design of WISE, prompts students to reconsider and distinguish scientific ideas on their own, rather than verifying the accuracy of answers or telling students to try again (Linn, 1995). One difficulty with the use of automated guidance in online environments is that students do not always engage and respond by making effortful revisions. When students are required to highly engage in these difficult activities, they sometimes feel discouraged and avoid the task (Chaiklin, 2003). This research program examines how to best design automated guidance that augments student agency to promote effortful use of automated guidance. Agency is defined as the power to take meaningful action and see results from one's decisions and choices (Basharina, 2013). People's beliefs about their capability to exercise control over specific events can affect "their level of motivation, as reflected in how much effort they will exert in an endeavor" (Bandura, 1989). Well-designed guidance may encourage students to make effortful revisions and ultimately improve science learning.

Study 1 demonstrates that automated knowledge integration (KI) guidance can promote understanding of science as effectively as simulated teacher (ST) guidance. Students who were given KI guidance showed significantly greater score improvements during revision than those with ST guidance. More students in the KI condition also made effortful revisions as opposed to surface level revisions. However, in this study some students still discounted computer guidance, assuming it was generic rather than personalized. Study 2 showed how communicating that adaptive guidance is personalized to students' responses rather than generic improved student revisions to their explanations. The transparently personalized guidance condition led to greater score improvements during revision compared to the standard adaptive guidance condition, and led to higher pre to posttest gains among low prior knowledge students. The amount of effort students invested in revision influenced overall learning gains, yet many students still did not use effortful strategies. Study 3 investigates additional methods to increase student agency in making effortful responses to guidance. Student agency was supported with a focus on one of two strategies, either revisiting evidence or planning writing changes, prior to revision. Preliminary findings illustrate that automated guidance can motivate students to integrate scientific ideas while improving revision strategies and supporting science learning. Data was collected from 11 teachers' sixth grade science classrooms in five public schools, which vary in demographics and SES. Data samples include students' initial and revised responses to the automated guidance question, as well as pretest and posttests. Logged data is used to evaluate student agency and use of revision strategies, and student interviews and videotapes are examined to give insight into students' conversations and thought process while using automated guidance. Both qualitative and quantitative analysis methods are used to bridge together research on student motivation and use of technology for science learning. Findings can be used by classroom teachers to strengthen agency in science inquiry, and to inform the design of online learning environments.

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