Reversing the Swing from Science: Implications from a Century of Research

ITEST Convening on *Advancing Research on Youth Motivation in STEM*

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Abstract

For at least the past 100 years science educators have been concerned about how best to encourage children's natural interests in science; but the problem of waning interest through the middle school and high school years persists. Research on how best to maintain interest in what is now more broadly conceived of as science, technology, engineering, and mathematics (STEM) is more important than ever. These studies can be categorized as deductive research that begin with theories of action and lead to interventions to be tested; or inductive studies that begin with existing programs, and lead to theories about why some are more effective than others. Given the importance of this issue for preparing a scientifically literate population and strong technical workforce, it is essential that researchers build on each others' work and communicate findings so as to influence policy and practice.

Part I. A Brief History of Research on Youth Motivation in STEM

John Dewey Lays the Foundation

John Dewey's seminal 1913 essay, *Interest and Effort in Education,* laid the foundation for educational theory and intervention in science education based on the central question of how to best motivate learners. The starting point of his theory of action was a definition of interest as "being engaged, engrossed, or entirely taken up with some activity because of its recognized worth." Dewey discounted the typical approach of motivating students by relying on a list of topics, such as dinosaurs, that most children find fascinating, and focused instead on a deeper level of engagement more recently referred to as "flow" (Chixantmihaly 2000) in which a person becomes so absorbed—think of what it must be like to be a rock musician performing for a thousand roaring fans— that passage of time has no meaning.

In Dewey's theory of action, interests can motivate people to undertake efforts that may not be immediately engaging (such as *practicing* the guitar) which enable the individual to develop further skills and knowledge, leading to intellectual growth and development. Also, he is explicit about the teacher's job—the intervention—that supports student motivation to continue learning and developing. Dewey presents his recommended intervention as a series of dos and don'ts that can be paraphrased as follows:

Don't…

- Use fear or coercion to make students learn difficult subjects, such as math.
- Sugar-coat learning by bribing students with goodies or affection.
- Assign tasks that are too difficult so that students give up.
- Assign tasks that are too easy, such as repetitive drills that bore students.

Do…

- Make an effort to understand what your students find intrinsically interesting.

- Provide an environment where students can pursue and extend their interests.
- Relate science to human concerns.
- Provide tools and materials for students to do real work.
- Challenge students to innovate and invent in order to pursue their goals.

Although Dewey's essay seems remarkably modern in its ideas about how to motivate students in STEM (notice the references to technology, engineering, and mathematics), it differs from modern articles in that it does not deplore students' lack of interest in science. Rather, Dewey takes a positive approach, implying that all students are naturally interested in learning about the world, and it's the job of a sensitive and capable science teacher to build on that interest in order to support students' intellectual growth.

Research on the genesis of interest in science

Interest in students' attitudes towards science was a major topic of educational research throughout most of the 20th century according to a research review of more than 400 studies by Oremod and Duckworth (1975). The first study they cited, published in 1874, was a study by Francis Galton of 100 Fellows of the Royal Society entitled *Men of Science: Their Nature and Nurture*, was that interest in science began very early, and in fact most scientists could not recall when they were *not* interested in science.

The number of research studies of schoolchildren's attitudes towards science increased substantially in the 1930s, including a survey of science interest among 9,000 elementary age children in Worcestershire, England. Further work in the 1940s and 1950s attempted to pin down the age at which children became interested in science related careers. A key study by Chown (1958) reported two peaks in the time of occupational choice—ages 13 and 16 for boys, and ages 11 and 15 for girls, who tended to mature earlier. Oremod and Duckworth concluded that: "The widely used evidence all points to the conclusion that, in the United Kingdom and the United States, at least, the critical ages at which pupils' attitudes to science can be influenced extend from about 8 years of age to about 13 or 14." (p. 4)

Sputnik Sparks Interest

Prior to the launch of Sputnik in 1957 science educators were aware that many students tend to lose interest in science sometime before high school, but it was not a major cause for concern for the nation. However, once the importance of a strong scientifically minded workforce came to be associated with national security at the start of the cold war, what was then called the "swing from science" began its climb to the top of the agenda for science education research.

A more recent review by Osborne (2003) that summarized findings from a selected group of about 150 key studies focused on the importance of a scientific-technical workforce for continued economic prosperity. The review pointed to the finding that students' interests in science tend to decline from age 11 onwards and expressed serious concern about the decline since 1990 in the number of students in the US and UK who choose to pursue STEM fields in college and graduate work in STEM fields.

Osborne found that various researchers conceived of "attitudes toward science" in different ways. Some emphasized the affective aspects of the construct, such as feelings, beliefs and values about science. Others emphasized the cognitive aspects, such as a questioning approach to the world, a search for data and their meaning, a demand for verification, and a respect for logic.

The affective dimension is generally referred to as "attitudes towards science" while the cognitive dimension is commonly referred to as "scientific attitudes."

A key finding of Osborne's review was the apparent contradiction between students' attitudes towards science in general and their attitudes towards science in school, especially at the high school level. That is, most teenagers, including both boys and girls, find science interesting and useful in everyday life. On the other hand most teenagers find school science, and especially physics, to be difficult, boring, and disconnected from society. Research studies strongly suggest that the reason for this apparent contradiction is the poor quality of school science teaching, and that the most important single factor in engendering positive attitudes is a knowledgeable and enthusiastic teacher.

The second most important factor in reversing the swing from science is the curriculum—how teachers engage students in science, both in school and informal science settings such as afterschool, Saturday and summer programs. Given that choosing an effective curriculum is somewhat easier to control than recruiting, training, and retaining the best teachers, it is not surprising that the largest number of studies by far have been comparisons of different science curricula, numbering in the hundreds, and possibly thousands. Osborne's review is critical of such studies because the great majority of them compared an experimental intervention with the normal curriculum, but failed to analyze the essential ways in which the two instructional approaches differ.

Part II. Inductive Approaches: Theories Leading to Testable Interventions

Taking Osborne's analysis to heart, this section focuses on three interventions and their theories of action that provide exceptional insights into what works in motivating youth to engage in STEM activities, to develop a personal interest in STEM subjects, and aspire to STEM careers.

DESIGNS: Focus on Teaching

Swartz and Sadler (2007) compared three instructional methods for engaging student interest in science while increasing their knowledge of science concepts. The interventions involved same content matter, the same hands-on activities, and many of the same instructional supports, so that they could analyze the effect of a single variable—the way that teachers and students shared responsibility for guiding instruction.

1) In the **traditional method** the textbook specified the instructional goals, strategies for students to use in reaching the goals, and the order of activities.
2) In the **discovery method** the students had the freedom to choose the instructional goals as well as the strategies to reach the goals.
3) In the **balanced method** the teacher set the goals while the students determined the strategies they would use in reaching the goals.

The unit being tested was about electromagnets, drawn from the DESIGNS curriculum that the researchers had developed. Two theories of action guided development of the instructional materials. The first was perceptual control theory, which emphasized the importance of goals that enable students to marshal their resources towards a specific end, to continuously evaluate their progress, and to make decisions about their own learning. Perceptual control theory predicted that the discovery approach would be the most motivating.

The researchers also wanted students to develop science concepts and skills. The theory of action to support that purpose was skill theory, which emphasized the importance of beginning at the level of action so that the students would become familiar with the various materials and properties of the electromagnet, and scaffolding their efforts to represent single then multiple variables, and finally advance to abstract thinking. Skill theory predicted that the balanced method would be best.

Student engagement was assessed by systematically observing the number of students on task (in "flow") and growth in knowledge was measured by a concept questionnaire that tested their understanding of electromagnetism and their ability to solve new problems that they had not encountered during the intervention.

The results of the study were that the balanced method, in which the teacher sets a well-structured goal, but the students have freedom to control their strategies and procedures in reaching the goal was most effective in motivating students and in gaining knowledge and skills. In contrast, students in the traditional condition were bored and tended to focus on what the teacher wanted, asking questions such as: "Is this right?" "Will this be on the test?" The students in the discovery condition were highly motivated, but at the end of the unit they had little grasp of how electromagnets worked.

The Schwartz and Sadler study provides an excellent example of a research design that avoids the methodological problems pointed out by Osborne, and that yields valuable information about how to accomplish affective as we as cognitive goals. However, its usefulness is limited to what can be done with the relatively short-term interventions that can take place in a science classroom. Such interventions rarely address the more profound obstacles met by youth of color, by girls who have received little incentive to engage in STEM, or by youth from communities of poverty. Consequently, we turn next to a pair of studies that—although variables are not controlled as they were in the Schwartz and Sadler study—nonetheless shed light on the kinds of interventions that may have substantial impacts on youth who are otherwise difficult to reach.

YouthALIVE! Focus on Multi-Year Engagement

YouthALIVE! (Youth Achievement through Learning, Involvement, Volunteering, and Employment) was a response by a small group of individuals within the science center community to a series of reports in the late 1980s that the talent and potential of too many young people was being lost. The result was *YouthALIVE*!, which may well be the largest experiment ever undertaken to engage youth from populations underrepresented in STEM fields. During the 1990s, the DeWitt-Wallace Reader's Digest Fund awarded grants to 72 institutions to establish programs that would primarily serve teens of color, youth from low-income communities, and girls from age 10 to 18.

Unlike most programs that would last a week or two, or occasionally an entire summer, the teens who joined *YouthALIVE*! were welcome to remain in the program from the time they joined (which could be as early as middle school) until they graduated high school. A typical program might involve the teens in both attending and teaching afterschool and weekend science classes, working in summer camps, serving as exhibit interpreters on the museum floor, or helping scientists conduct research. Common factors among programs were frequent contact, a club-like atmosphere, dedicated staff with youth development experience, and a focus on learning, teaching, developing a strong work ethic and a sense of community (ASTC 2001).

Although institutional grants ceased more than ten years ago, a recent retrospective study (Sneider and Burke, 2011) found that the number of youth programs at museums and science centers has grown to 163, demonstrating that philanthropic initiatives that are thoughtfully planned in collaboration with museums and science centers, meet multiple needs, and are based on clear principles, can survive and thrive when major funding ends.

Although not all programs have been evaluated, those that have present a remarkable record of success at greatly reducing the number of high school dropouts and increasing the number of minority youth and girls who choose careers in STEM fields. For example, Chi and Snow (2010) conducted a ten-year longitudinal survey of former participants from Project Exploration (PE), a nonprofit organization in Chicago that recruits minority youth and especially girls to go on field expeditions with paleontologists and to work with visitors in the city's science museums. The researchers found that 95% of the respondents have graduated high school or are on track to graduate, nearly double the overall rate of Chicago Public Schools. In addition, 61% of students currently enrolled in a four-year college reported pursuing degrees in STEM-related fields; and 59% of four-year college graduates reported earning a degree in a STEM-related field. These findings are especially remarkable since PE recruits students who do not necessarily do well in school or who are not initially interested in science.

A theory of action that helps to explain the success of multi-year programs for youth is the Trilogy of Success theory (Jolly, Campbell, and Perlman 2004) which identifies three factors as essential for all students—and especially youth of color, those who come from communities of poverty, and girls—to succeed in science: *engagement* to increase student interest and motivation; *capacity* to gain knowledge and skills, and *continuity* of material resources and guidance by caring individuals. The *YouthALIVE*! model provides all three factors, including the very rare factor of continuity, over a period of several years.

However effective and important such programs may be, they are resource-intensive, and consequently available to only a small fraction of the many youth who could benefit. Consequently the next program to be reviewed requires very few resources and could therefore affect a great many youth.

Perceived Relevance: Focus on Introspection

Hulleman and Harackiewicz (2009) designed a rigorously controlled experimental study to determine if personal relevance would affect high school students' interest in science, performance in the course, and interest in science related careers. The researchers based their study on an expectancy-value theory of action that predicted students who had low expectations of success in science would benefit more from an intervention that increased the perceived relevance of the course than students who had high expectations of success, and therefore did not need a motivational boost.

The study was conducted with the assistance of seven high school science teachers from two high schools and 262 students enrolled in biology, integrated science, and physical science. All of the students received. Although the notebooks appeared to be the same, half the students in each class received notebooks that instructed them to write about the usefulness and value of the course material to their own lives; while the other half of the students received notebooks that instructed them to summarize the course material. The teachers did not know which students received which instructions.

All students were administered questionnaires about their interests in science and their expectations of success at the beginning of the semester. At the end of the semester they answered questions about their interests in science and their career aspirations. As predicted, the students who had low expectations of success at the beginning of the course had significantly more positive attitudes towards science. Students in the experimental condition improved their science grades an average of two-thirds of a letter grade during the subsequent quarter. The intervention was equally effective for boys and girls and for students of all races. In contrast, there were no significant pre-post differences for students who entered the course with high expectations.

The researchers noted that this degree of improvement for students who were most in need was comparable to other social-psychological interventions aimed at reducing the back-white achievement gap. In contrast with the high cost of multi-year programs that could serve relatively few students, having students occasionally write about how the course they are taking is relevant to their lives is a low-cost and easily implemented intervention that could be implemented by any teacher in either formal or informal science education settings.

III. Deductive Approaches: Explorations Leading to Theories of Action

Each of the studies reported in Part II tested a specific intervention that followed logically from a theory of action. Consequently they each exemplified a *deductive* approach to the science of motivation. An alternative approach is *inductive*—to explore the results of many different programs, look for positive effects, and formulate theories about why the effective ones work and the ineffective ones don't. The advantage of an inductive approach is that the researcher is not limited to testing their own hypotheses; but instead is open to what the data have to say. This paper ends with a brief summary of three inductive lines of research that are currently ongoing.

Longitudinal Studies of Multiple Programs and Pathways

A line of research by Robert Tai and his colleagues, based at the University of Virginia have taken an approach similar to the earliest researchers in the field. They interviewed 116 scientists, engineers and graduate students in STEM fields and find out what influenced them (Maltese and Tai 2010). Consistent with the findings of the Royal Society study in 1874, interest in science began very early. The majority (65%) reported that their interest in science began before middle school. Women were more likely to say their interest was sparked by school-related activities, while most of the men credited activities they initiated themselves. The researchers concluded that current efforts to increase our nation's scientific and engineering workforce by focusing efforts on higher test scores and encouraging more students to take advanced science courses may be misguided; and it may be more important instead to focus efforts on engaging boys and girls in science at the elementary and middle school levels.

In one of the most widely cited research studies on motivation in STEM Tai, Liu, Maltese, and Fan (2006) conducted an analysis data from the National Education Longitudinal Study (NELS). NELS surveyed 24,599 eighth graders in 1988, and followed up with surveys of the same youth in 1990, 1992, 1994, and 2000, when the participants who were 13 years old in 1988 were 25 years old. The study also collected data on the students' performance on mathematics and science achievement tests. By the end of the study period 3,359 of the youth surveyed in 1988 had obtained four-year college degrees. College majors for these students were coded into three broad categories, physical and general science, life science, and non-science.

The 8th grade survey asked the participants: “What kind of work do you expect to be doing when you are 30 years old?” Students were given a list of career options and asked to select just one. Responses were categorized as with “science” or “non-science.” Findings were that students who expressed interest in science-related careers in 8th grade were 1.9 times more likely to go into the life sciences, and 3.4 times more likely to go into physical sciences or engineering than those who chose non-science career expectations.

To follow up on the implications of the earlier studies Tai and his colleagues are currently researching the effects of 50 or more different programs aimed at engaging children and youth in science, and in longitudinal studies that connect the dots between early engagement and later achievement and career choices.

The Science Learning Activation Lab

Rena Dorph and colleagues at the Lawrence Hall of Science, UC Berkeley, have undertaken an ambitious program to determine how to activate children’s interest and persistent engagement in science learning and inquiry (Dorph, Schunn, Crowley, and Shields 2011, p. 16). Noting that nearly all research on this important topic is confined to specific programs or take place within limited categories of science setting (schools, museums, afterschool programs, etc.) the purpose of the Science Learning Activation Lab is to investigate the features of excellent science education that apply across settings. In an effort to identify measurable outcomes, the researchers identified the following dispositions that together describe a science-activated learner: curiosity, motivation, responsibility, persistence, science capable, identity, appreciation, and interest in science. A major goal of the Science Learning Activation Lab is to develop a valid and reliable battery of test instruments to measure all eight constructs.

These lines of research will come together in a series of coordinated longitudinal studies to provide valid, reliable, and predictive measures of dispositions that signify activated science learners, and features of educational programs that foster those dispositions. The researchers will use both quantitative and qualitative research methods to study the features of effective educational interventions in a variety of different settings, and the various pathways through different settings taken by individuals on their way to becoming activated science learners.

The Synergies Project: Investigating Science Motivation in Situ

Falk and Dierking at Oregon State University have undertaken a study of how the full spectrum of formal and informal learning experiences affect individuals’ interest and engagement in science during the critical years between 5th grade and 8th grade The researchers have identified the Parkrose School District, a large neighborhood with its own school district in Portland, Oregon, as the unit of study. The research method will be to study a single cohort of about 300 children as they attend school, take part in activities outside of school, go on field trips with their families, watch television, and all of the experiences that the children are typically exposed to. The children will be interviewed individually, as will their siblings, parents, and friends. Local formal and informal science educators will also be interviewed to understand their goals and the kinds of programs they offer. In all about a thousand people will be interviewed, and a focal group of about 50 children will be interviewed several times during the course of the study. A unique element of the study is to engage some of the high school participants in collecting and offering their own hypotheses about the factors that contribute to motivation in STEM.

What Have We Learned in a Century of Research?

This paper only brushed the surface of an extensive and multifaceted body of literature on how to motivate youth to engage in STEM related activities, courses, and careers. Consequently, it does not serve the purpose of an extensive review of the literature, such as those provided by Ormerod in 1975, or Osborne in 2003. Nonetheless, some consistent findings are apparent:

Attitudes are malleable. Thousands of studies how demonstrated that a wide variety of interventions can increase young people's engagement, interest, and career aspirations in STEM fields. These studies have ranged across a wide variety of formal and informal settings, with boys and girls of various ages, from different ethnic and cultural backgrounds.

The critical period for influencing students is between 8 and 13 years old. Perhaps the most consistent finding throughout the century is that people who eventually succeed in STEM careers developed their interest early in life. Formal and informal programs to increase interest and engagement in elementary and middle school have been very successful, and the current focus on test scores at all age levels may be counterproductive.

Young people like science—though not necessarily in school. Osborne's extensive review (2003) highlighted findings that the great majority of boys and girls like science and related fields; but are turned off by poorly taught courses in school, especially high school physics. So even if they come to high school with high hopes of engaging in a pathway leading to a career in science or engineering, young people can discouraged by a negative high school experience.

Teachers, teaching methods, and curriculum can make a difference. Whether in formal or informal settings, knowledgeable and skillful teachers have tremendous power to get kids interested in STEM. Teaching methods that succeed in tapping students' personal interests and engaging them at a deep level ("flow") can be very effective in increasing the pool of science-interest learners.

A diversity of research methods is needed for further progress. Educational research can be sliced and diced in a variety of ways, such as qualitative vs. quantitative, formal vs. informal, evaluation vs. research, etc. This paper used the distinction between deductive vs. inductive approaches to illustrate two very important and valuable approaches that ask different research questions. *Deductive* approaches start with a theory of action for how to motivate youth, and ask, "which interventions are most effective?" *Inductive* approaches begin with existing interventions and ask, "What theories of action can best explain why some youth become motivated science learners and others do not?" The two approaches are complementary, an together help to ramp up the quality of STEM education programs—provided that communication among researchers, practitioners, and policy makers is effective and timely.

Given what is at stake—the scientific and technological literacy of our population, and the future of our nation's technical workforce—it is important that we pay attention to findings from the full range of prior studies, think deeply about the kinds of research that still need to be done, and communicate effectively both within the research community and with those who are well positioned to put these findings (incomplete though they may be) to work by improving practice and formulating national policy.

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Building Engagement With Technology-Enhanced Local Learning

White Paper for the National Science Foundation Convening on
Youth Motivation and STEM Workforce Development Experiences

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Abstract: Drawing on a multi-year research and development program, the authors report on the promise of integrating locally-focused student investigations with ubiquitous access to advanced technologies. By doing this, students are better able to see the relevance of STEM skills and knowledge as they work to improve their local communities. Specific program examples cited show the paradigm as it has been implemented with upper elementary and middle school students. Contrasting examples show challenges in implementation. A four-part framework of essential program elements is offered to guide further investigation.

Overview

While much technology use in schools is greeted with fanfare, transformative impact has been harder to document. In most cases, the technology is co-opted to serve the prevailing transmission-driven school paradigm. Additionally, there is evidence of a split between technology use in and out of school, with many students not seeing how the technology they use in school relates to learning or future career choices (Selwyn, Boraschi, and Ozkula 2009; Selwyn and Husen 2010) . All too often, the end result is that some students end up with a great deal of technological expertise that they are not allowed to use in school, while others (often from rural and/or socio-economically challenged communities) don't have the same experiences. While reduced, the digital divide is still all too present in American society. We believe that well-designed formal and informal learning experiences can play a pivotal role in bridging both the socio-economic and relevance gaps.

Whether embedded in the regular school day or in out-of-school settings, STEM-rich experiences that have practical relevance can engage students as they build citizenship and workforce skills. As students see real-world applications of STEM disciplines, their horizons expand. The world becomes more understandable, and they come to see themselves as competent learners. Within that broad realm, we have found that locally-focused projects are particularly valuable as the foundation for students' learning experiences. In the sections below we detail our work with a variety of geospatial, augmented reality, and agent-based modeling tools to enhance community-based investigations. Most of this work is with upper-elementary and middle-school students, but we are confident that the general parameters extend more broadly.

Theoretical Framework

This discussion builds on the general framework of place-based education (Sobel 2004; Smith and Sobel 2010) and on uses of advanced technologies, arguing that there is potentially a great benefit to be realized through their synthesis. As an umbrella concept, "place-based education encourages teachers and students to use the schoolyard, community, public lands, and other special places as resources, turning communities into classrooms" (Place-based Education Evaluation Collaborative

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2010). Beyond this broadly framed anchoring in the local, there are at least two foundational aspects that characterize high quality place-based programs. The first is increasing student ownership of the projects, as articulated by Hart (1997) in his ladder of participation. As Hart points out, having students "involved" can mean anything from token involvement up to full collaboration with adults in the community. Along with this focus on increasing student agency is the goal — at least for environmentally focused projects — of helping students become what Chawla (2009) calls "an agent of care for the natural world." Together, these elements root students in their community and equip them to make a positive contribution.

In tandem with these elements of place-based learning are a range of spatially anchored technologies, including geographic information system (GIS), global positioning system (GPS), and augmented reality (AR) tools. Each of these offers opportunities for students to extend their thinking beyond direct experience with the local community. When they do this, they create what Gordon and de Souza e Silva (2011) refer to as net localities. As they describe it, "net locality implies a ubiquity of networked information – a cultural approach to the web of information as intimately aligned with the perceptual realities of everyday life. We don't enter the web any more; it is all around us" (pgs. 2-3). Thus, there is a real need to help students live in both "real" and networked spaces, drawing from both as they define their place in the world.

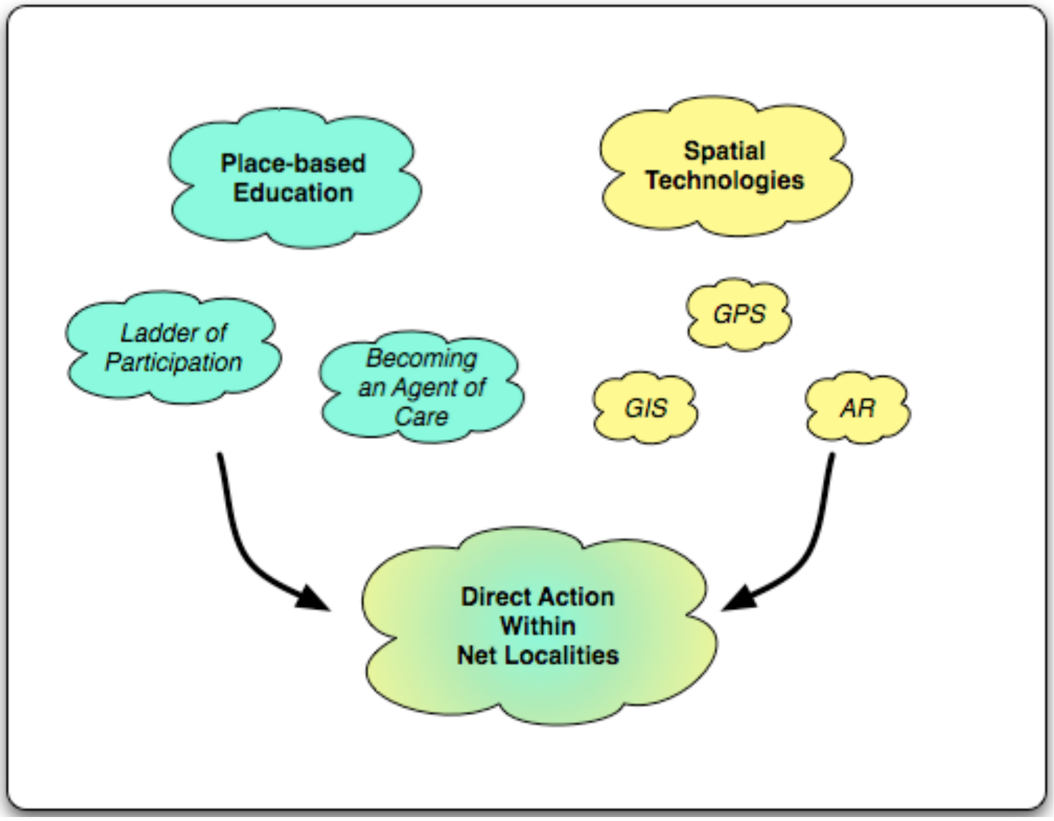

Fig 1. Integrating place-based education and spatial technologies

Cross-program research (Duffin, Murphy and Johnson 2008) has found that local projects in which students collect measurable impact data (e.g. measured pollution mitigation, not just advocacy) lead to higher student interest and learning. While some might argue that project-based learning situated in real contexts takes too much time in an over-crowded curriculum, data such as this provides an effective counterpoint. Students with meaningful tasks will be motivated to engage with complex material more readily, and will be better able to integrate what they are learning into robust conceptual networks. As Gee (n.d.) notes, "a large body of facts which resist out of context memorization and rote learning comes free of charge if learners are immersed in activities and experiences which use these facts for plans, goals, and purposes within a coherent knowledge domain." School learning on the other hand often remains detached from any real-world consideration, with students going through the motions and generating answers with no practical application. Schoenfeld (2010) cites as an example the classic school problem in which a given number of people need to ride a bus. Knowing that each bus can hold so many people, how many buses are needed? As a school math exercise, many students respond with a remainder or offer a solution involving fractional buses. Anyone solving it as a real problem wouldn't generate these answers, since moving real people doesn't allow for leaving some behind or having partial buses. When we move from the academic to the authentic, we can better support student learning.

Coupled with the benefits of authenticity, in many cases the immediate proximity of local contexts fosters greater student interest and enables students to take direct action in which they employ their STEM skills. Students are much more likely to care about the health of a local creek than about abstract considerations of water quality. Likewise, mountains thousands of miles away are less interesting than the mountains on the students' horizon. Aside from the potential to spur interest, the local context favors taking constructive action. While many students are led to advocate and raise funds on behalf of saving a distant rainforest or protecting a charismatic but endangered species, they can actually get involved in a local native plant restoration project. From the standpoint of learning and capacity development, we believe — consistent with Hart's ladder of participation — that direct action with constructive mentoring is far more educational than advocating that others in a distant land take action at the students' behest.

To be clear, this focus on the local is not a call for parochial worldview. Rather, the local investigations help to build a framework that can be used to understand the distant. For example, one of the authors of this paper was a teacher whose fourth grade students were investigating biomes. Rather than doing a simple cataloging of different ecoregions, they began their work in a patch of woods across the street from the school, studying life in the temperate deciduous forest. Linking field study and classroom work, they used a variety of text and online resources to identify species and reconstruct the local food web. In parallel with this, they used databases to link abiotic and biotic features, over time learning how adaptations favor survival. Building on this strong foundation, they were able to use this interpretive framework to understand distant regions, culminating in multimedia presentations on life in different global biomes (Coulter 2000). Framed well, a "local to distant" scope helps students to become well-grounded global citizens.

Research Context

This paper builds on the findings of a joint 3-year effort by the Missouri Botanical Garden (MBG) and the Massachusetts Institute of Technology (MIT) to build students' STEM engagement through technology-enhanced local learning. Supported by the National Science Foundation and private funders, MBG and MIT have developed a range of projects that leverage geospatial, augmented reality, and agent-based modeling tools. Most of these projects also embed service-learning opportunities that enable students to apply and extend their learning. Examples of recent projects include:

- Middle school students using preliminary data and ArcGIS to track an EF-4 level tornado that struck their neighborhood only a week before. Although students had personally seen homes and businesses that were leveled, it wasn't until they mapped the tornados to see the path of destruction that real inquiry began. Starting with this high-visibility event, they went on to map seasonal variation in the likelihood of tornado strikes across the country and to investigate real data in depth. Student-driven questions included thought provoking queries such as *"Texas has a lot of tornados, but they also have a lot of land. Is there another way to investigate frequency? How does Texas compare if we map tornados per square mile?"*

- 6th grade students using agent-based modeling via StarLogo TNG to learn about bioretention as a tool for managing storm water run-off. In the model, students make sense of their efforts to improve a local habitat by adding areas devoted to native plants. Areas planted with deeper-rooted, native plants are capable of absorbing more runoff, mitigating flow into drainage channels. By adding virtual native plants into the model and re-running scenarios, students are able to model the intended impacts of their efforts by compressing time and space. The students also gain valuable experience using modeling as a tool for scientific inquiry.

- 4th and 5th grade students learning about water quality in their neighborhood park through an augmented reality game. While the students had played in the park for years, they hadn't noticed the ecological impact of how people use the park or the impact of surrounding businesses. Challenged by an environmental mystery created with augmented reality software, students completed first hand investigations of the park while "meeting" virtual residents and professionals on handheld computers. Meeting back together at the end of the investigation, students shared the evidence they gathered to determine what was causing a real-life water quality concern.

Program evaluation data indicate that the joint focus on advanced technology applications and high-interest local issues can engage a broader range of students than more traditional methods. Programs such as these correlated with higher levels of student and teacher interest, and gave evidence of students actually using STEM concepts and technology skills in their work. The fusion of interesting local contexts and opportunities to apply what they are learning appears to be creating positive, self-sustaining energy within the program.

In contrast, other programs we supported failed to achieve this level of engagement, remaining in a passive academic mode for teachers and students. Even though the program ran in after-school and summer settings (and thus, participants were freed from burdensome standardization and accountability requirements), the tasks didn't break out of the traditional paradigm of school exercises. Thus, real contrasts emerged in our portfolio of schools between the active, investigatory programs and more passive ones. On the one hand, we had students using geographic information system (GIS) tools to investigate socio-economic inequalities in access to healthy food while others photocopied local history facts and mounted them on construction paper.

Findings and emerging conclusions

Given the stark contrast in program outcomes, it is clear that simply basing a project in the local community is not sufficient. Rather, it is an enabler of certain attributes that are desirable for promoting STEM involvement. Specifically, we have found the following to be important program elements:

- Strong adult leadership with appropriate STEM pedagogy
- Access to local human, physical, and cultural resources
- Technology resources that enable active investigation and sense-making
- Administrative and parental support for active learning

By far the strongest predictor of a successful program was the quality of adult leadership. The programs supported by the MBG-MIT partnership all employed teachers to lead after-school and summer programs in addition to their "regular" school duties. In the more successful programs, teachers embraced what Gee (n.d.) has described as post-progressive pedagogy, offering "a well-integrated combination of embodied immersion in rich experience... and scaffolding and guidance [for students]." The key is to move past dry "teaching by telling" on the one hand and just throwing kids into experiences on the other. Instead, he argues, learners need immersion in experiences and the support of more expert guidance. In this context, the expertise needs to be both in the relevant content domains and in learning. While one could quibble with Gee's dismissal of progressive pedagogy as not providing adequate support, his vision of supported engagement is on target. More than simply doing activities, students in our more successful programs had a sense of purpose and direction to their work, with clear accountability to others who would benefit from their work. Programs generating less student enthusiasm were stuck in "school mode," characterized by a level of passivity among teachers and students. Virtually every week needed to be scripted by the program staff, with little effort by the teachers to engage in active exploration.

Strong pedagogy on the part of the teacher-leaders is necessary, but much more is required for projects to succeed. Leaders also need to be able to marshall the physical and human resources that extend the range of possibilities. Thus, a stream investigation benefits from high-quality testing kits and mapping tools. Likewise, a local food project benefits from partnerships with community supported agriculture (CSA) groups. Giving student investigators access to high quality tools and connections to people working in the field makes the project more authentic as "real" tools are used and students can see adults in the community who value the work at hand. These adults can then become mentors and role models for students forming career aspirations. More generally, the addition of tools and people helps the project stop being a school exercise. Instead, students are now part of a valued community endeavor.

A third critical dimension we have found is effective use of technology to support student inquiry. While virtually anyone today can look up facts through search engines, technological enhancement to post-progressive pedagogy requires a higher level of commitment on the part of teachers and students. Our work has focused on constructive uses of geospatial, augmented reality, and agent-based modeling tools, but there are many other resources (such as probeware) that offer similar benefits if used well. The critical distinction is in how the technology supports student thinking. Technology limited to fact searching reinforces a learning model of knowledge accumulation. More engaging uses of technology can support complex thinking as students engage in geospatial analysis, build models, and see their community from a new perspective through augmented reality. A key test is whether students go beyond simply having more information and toward seeing the community differently as a result of technology integration. As noted earlier, a net locality has strong integration of real and representational environments.

Fourth, strong administrative and parental support is required. Community-based study requires presence in the community. If administrative restrictions keep students on the school grounds (or worse, in the classroom), projects cannot achieve the level of significance envisioned here. For out-of-school projects, parents may be called upon to provide transportation to local field sites and help with weekend monitoring. Both administrators and parents need to be comfortable with the minimal amount of risk involved in field study. A creek project, for example, requires proximity to water. Policies that prohibit students being near water are counterproductive. All of the adults involved need to be comfortable with the concept of “manageable risk” (Tulley 2011) and help students to act responsibly in their field study.

Done well, programs that embed these elements create a fusion of energy that helps research teams sustain themselves and provide an “identity home” that nurtures students’ STEM identities. More than just an enclave for techie nerds, these projects build links between students interested in technology (who gain experience in a range of STEM fields in which their skills can be applied), and students interested in impacting their community (who learn that STEM skills enable greater understanding of their community). Over time, students who start with dissimilar interests come to appreciate and share diverse interests as they create STEM-based inquiry teams.

Discussion

While technology-enriched place-based education won’t address every curricular need, we have found it a compelling way to frame a wide variety of investigations. Viewed more broadly, the underlying principles apply in a wide range of learning contexts. Giving students opportunities to apply their knowledge in authentic contexts and to see how their STEM skills and understanding make a difference are essential components of engaged learning. In turn, this enhanced engagement is required for 21st century citizenship.

For all of these reasons, the synergy between place-based education and technology holds promise as a strategy for addressing current limitations in traditional schooling. Implicit in the work described here is a real trust in teachers and students to make good choices. Both have to be seen as capable of exercising sound judgment, though mentoring is likely to be needed to guide optimal program design. Provision of “more able assistance” (Luckin 2010) through mentors can help in project design and execution, but there is no substitute for giving learners of all ages opportunities to exercise judgment so that they can better own the project at hand and build capacity to make better judgments in the future. Teacher-proofing and kid-proofing the curriculum is all too common today as pacing charts and mandated curriculum resources keep everyone following a script. Realizing the vision presented here will require a paradigm shift in how we see the roles of teachers and students.

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Becoming Community Science Experts in Green Energy Technologies

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Abstract

In this white paper we describe youth engagement in cyber-rich science in a community setting, involving both knowledge/practice development and identity work through scientifically rigorous, culturally responsive, and generative activities. This model for youth engagement, which we refer to as the "becoming community science experts model" (CSE model) is grounded in critically-oriented sociocultural perspectives on learning which challenge traditional notions of expertise, and accounts for the ways in which the complex relationships between science, community/place and self frame science learning and engagement. Using longitudinal case study data of urban youth from lower-income and African American backgrounds who have participated in a community-oriented informal science program (GET City), we describe the model and suggest pathways towards CSE development in informal learning environments. We further use longitudinal data to make a case that this kind of engagement in science fosters science literacy as called for in current science education frameworks.

> *"We know what we are doing. We know how to make a difference. [We know] how to save energy and how to convince other people of better ways to do things with electricity. That is one way that we are experts. The roof is probably the best example because we actually helped the club save money. They spent a lot of money getting the roof but now they have probably already saved enough to get that roof again. In the long run it saved money."*
>
> *"What I would like do in the future, what I want to be when I get older, is become an engineer specializing in Computer and Electrical engineering or Reverse Engineering. I would like to invent or create something that will save energy, and be very useful to people, that will cost less. I would love to create an energy-efficient refrigerator, that will use less, and maybe tell you how and what items that are still in the refrigerator. I am aware of energy-efficient refrigerators that are currently in the market, and I am very interested in learning about how such refrigerators are actually designed and made."*

These two opening quotes are from Janis, a 13-year old African American and in-coming 9th grader who has participated in GET City for nearly 4 years, first as a student-participant and later as a youth leader. She refers to herself as a "make-a-difference expert" and wants to be an engineer as a future career. This identity is new for Janis, who, in 5th grade (when we first met her), openly expressed a dislike of science, was unfamiliar with engineering, and aspired to be a singer. Janis' emerging science/engineering identity is tied to her desire to use her artistic ability to contribute to the world. Janis describes GET City as the place where she learned what an engineer is and where she realized she could use art to do science and engineering. It was also a place where she learned that being smart in science was not something only for "geeks."

What does it mean to become a community science expert? Why should this matter in the world of informal science and engineering programming? In our white paper we develop and describe an empirical model – the "becoming engaged community science experts" (CSE) model – based in mixed methods longitudinal case studies that explains youth engagement in science in the context of the GET City program (see Calabrese Barton & Tan, 2010b). Green Energy Technologies in the City, or GET City, is a year round after school program that encourages participants to develop knowledge, skills, and dispositions needed for participation in STEM. In particular, GET City emphasizes youth development into *STEM experts and citizens* who use cyber tools to take on scientific problems of local relevance and global importance, and educate others on their investigative findings. GET City is built on the premise that meaningful learning happens when youth engage in authentic investigations of local problems, and have scaffolded opportunities to communicate and educate others about those investigations.

We seek to answer the following questions:

- What does it mean to become an engaged community science expert in the area of green energy technologies?
- What knowledge, discourses and practices related to green energy technologies do youth take up, and how does this frame their participation, decision-making, and learning?
- What is the relationship between becoming a CSE and becoming engaged in STEM?

After first presenting our conceptual framework, we describe the GET City Strategies Project, and offer a fairly descriptive set of design principles which guide our work on the project. We use these design principles to help us to describe and explain how and why we believe that youth identity development as community science experts is crucial to their learning and engagement in green energy technologies.

Conceptual Framework

While there is a growing body of research focused on identity development and science learning, little of this research looks at how such identity formation is framed by youth engagement across the different worlds that make up their lives, and in particular, how such identity is deeply situated in place-based science learning. We know that the influence of many out-of-school experiences that youth have are deeply influential in how they author possible selves in science. We draw from sociocultural studies of learning and identity, which frame learning as a cultural process (NRC, 2009) that involves guided participation (Rogoff, 2003) or apprenticeship (Lave &Wenger, 1991). Such work calls attention to learning as an embodied activity, involving the on-going recreation of practices, roles and identities among individuals in social networks and over time (Nasir &Hand, 2008). Identity work, which happens as a part of learning, involves the production and reproduction of identities via participation in activities and in relationships with others (Holland et al1998). A challenge in *understanding identity work as a part of learning*, is in understanding how identities become reified within and across communities as youth take up new ideas and understandings within and across communities.

However, not often discussed in the literature on science learning is the focus on the "horizontal dimensions" of learning – a focus which speaks to the cross community work that youth do. Gutierrez (2008) explains that, unlike a focus on vertical movement from "immaturity and incompetence to maturity and competence," horizontal learning focuses on expertise that develops within and across practices and communities (p. 149). Horizontal learning emphasizes the distributive nature of learning as well as the repertoires of practices that individuals cultivate as they move through space and time.

Horizontal learning raises questions around what it means to develop as science learners or to become expert in science. Such a view of learning is important because little attention outside of equity-driven research has focused on how learning is informed and transformed by the sociopolitical dimensions that shape everyday activity, and how and why youth come to understand their worlds. It is therefore important to note that as individuals gain access to new communities of practice, learning also involves a process of cultural production. We also know that when and how youth are supported in leveraging out-of- school resources, they increase their opportunities to learn science (Calabrese Barton & Tan, 2009; Rosebery, Ogonowski, DiSchiro & Warren, 2010). It is also important to note, however, that as an individual joins a community, he or she brings with them resources in the form of particular historical and cultural experiences, which by their activation can transform the discourses and practices of the community. As novices leverage resources from outside the community to develop expertise within the community, they create new discourses and practices that can transform its culture, discourse and practices, reflecting both vertical and horizontal development.

GET City Strategies Project

The GET City Youth-based program. Since 2007, GET City (http://getcity.org) has involved over 120 youth (~30 youth/yr) from low-income and under-represented backgrounds in Lansing, ages 10-14, in a year-round program that provides opportunities to develop scientific research skills and conceptual understandings related to green energy technologies, and job skills development for the growing IT market. Every Tuesday and Thursday, after school, for 24 weeks each school year, and for 3 summer weeks, youth have engaged in **authentic investigations** on locally relevant and globally important issues in green energy (e.g., Should our city build a new hybrid power plant?), translated their findings into powerful **cyberlearning tools** (e.g., digital public service announcements, wikis/webpages, etc.), and designed and implemented education lessons and workshops for peers and community members through the **GET City Education Network** on green energy in culturally relevant ways (e.g., teaching lessons about the technological design for energy efficiency in their school classrooms). These three components have been enriched by a powerful **GET City partnership**, which has provided youth with opportunities to interact and build relationships with engineers and IT specialists across the green energy sectors in their city, including research, education, business and the community (see Table 1 for an overview of the program).

Table 1: GET City Curricular Units

	Green schools & homes (Year 1)	**Green and Go** (Year 2)	**Science Ed & Climate Change Standards**	**IT skills and workforce standards**
Efficiency & Conservation	**Energy Crisis!** Investigation of electrical production, supply& demand; and how supply & demand are impacted by policies and practices	**Complete streets** Investigation into transportation and the environment using GIS to map access & impact of complete streets	*Energy and its forms:* • Energy is the ability to do work • Energy conversion *Energy and the environment:* • Traditional electricity production and use emits pollutants that cause health & environmental problems • Relationship between carbon emissions & climate change *Energy technology* • Compare & contrast forms of renewable energy: biomass, wind, solar *Climate change & environmental sustainability* • Strategies to reduce greenhouse gas emissions: alternative sources & change in how humans use energy. • Individual & community actions influence climate.	• Interaction with practicing IT professionals in multiple settings • Collaboration with peers and experts using IT tools • Content-specific tools & software to support learning & research GIS • Digital Probes • MS Excel • Digital photography & video production • Electronic concept mapping • Web surveys • Design, development, & publish communication products: • technical presentations • web authoring • digital videos • podcasting
Alternative Energy	**Powering the City!** Investigation into alternative energy through the design of a hybrid power plant.	**Cars of the Future** Investigation into the design of alternatively powered vehicles & environmental impacts		
Green Design	**Summer Synthesis** LEED-certified building design	**Summer Synthesis** Designing Fuel cell cars		

Design Principles

GET City has been built and refined on five design principles that align with IT Standards & Workforce Development Goals (U.S. Dept. of Labor, 1991), Cyberlearning and workforce development (Borgman et al, 2008), National Science Education Standards (NRC, 1996), Climate Change Standards (AAAS, 2009), and advances in informal learning (NRC, 2009; Friedman, 2008). The five design principles are:

1. Integration of cybertechnology and cyberlearning strategies develop scientific understandings, support complex reasoning, and foster increased interactions.
2. Local, authentic investigations that link scientific ideas with everyday practices and concerns support the development of STEM expertise in culturally relevant ways.
3. Taking action and positioning youth as experts in their community develop STEM citizenship.
4. Youth development is supported by continuous and complementary community based programming.
5. Distributed expertise and decision-making through involving local experts support expanded opportunities for learning and meaningful participation in STEM.

Framing Engagement & Motivation: Becoming Community Science Experts

We argue that youth engagement in GET City can be characterized by the process of becoming engaged community science experts (CSEs). This process is supported by the design features of GET City (described above) that work synergistically to support substantive youth learning and interest in green energy and that allow for youth to: 1.) Work side-by-side with practicing scientists and engineers to become experts on issues of green energy technologies as they collaboratively investigate real-world, real-time design-based problems of various scales, such as the design of a proposed hybrid power plant in their city or of a new green roof for their Club; and 2.) Use their expertise to author tools and resources for educating their community on these issues in ways that are culturally relevant, scientifically rigorous, and aimed at making a difference.

These features allow science knowledge and practices to be situated and progressively developed through activity in design-based work for *learning* and *educating others* (Brown, Collins & Duguid, 1989; Kolodner, 2006), while at the same time they support youth border crossing as they seek to bring science to their communities. Such side-by-side science and teaching practices support the youth in developing core science practices at the same time as they have opportunities to practice leadership and authority in science as they educate less knowledgeable others in locally meaningfully ways (i.e., siblings, parents, community members). For some of the girls in GET City, such engagement as CSEs appears to transfer to school settings, where they hold an "I'm an expert" attitude. We share the following example to help contextualize our point.

Jana: "Make a Change"

Jana is a vivacious 6th grader who attends the local elementary school adjacent to the Club. While small in stature, she exudes confidence. Jana joined GET City in the Fall 2008, in part because her older sister had participated in GET City the previous year and she was eager to participate in some of the activities and to gain access to the computers while learning more about the environment.

Figure 1: Make a Change

In Fall 2009, Jana participated in a unit investigating electrical production, supply and demand in her city and its relationship to energy conservation and efficiency. The investigation was framed through the "change a light, change Michigan" initiative that linked energy concepts with energy policy and practice. Jana conducted experiments comparing power requirements, heat and light output of compact fluorescent light bulbs (CFLs) and incandescent light bulbs using digital probes and spreadsheets. She made her own electricity using a hand crank and a bicycle, visited the local power plant to learn how the city was powered and how the plant worked to reduce the impact of burning coal. She conducted a light bulb audit in her school, documenting the number of incandescent bulbs that could be replaced with CFLs, then calculating how much money and carbon emissions would be saved. She prepared a 4 min documentary ("Make a change") explaining the differences between CFLs and incandescent light bulbs in terms of power consumption, fossil fuels, carbon emissions, pollution and monetary cost (see also figures 1 and 2). With other GET City youth, Jana used the movie and a demonstration experiment to educate her school's student government. With support from the Lansing Board of Water and Light, Jana provided over 50 CFLs to the school at no cost. She submitted her documentary to the "Show Green! Student Film Challenge," a *state-wide* competition organized by a Michigan nonprofit, and won first prize for the under-12 category.

Jana's participation at GET City illustrates how she built STEM expertise, created a cybertoolkit in her artifacts (PSA and movie) for STEM citizenship, and brought her expertise and toolkit to educate a broader school and internet audience as a community science expert (Sato, Calabrese Barton, Rose & Birmingham, 2011 for an in-depth description of Jana's experience). She said of her work on the video:

> You have to know about your community if you are going to make your investigation really make a difference. So, you have to know more than just the science you are doing. I mean no one really cares about

> carbon dioxide. Really. They don't. But when you explain how it actually impacts the global warming and using the CFLs saves money too, then people will

Figure 2: Overview: Make a Change
The video begins with the song, "waiting on the world to change". The first image shows youth appearing to enjoy themselves as the text "Grove Street Elementary School" appears. Two additional images follow of an incandescent light bulb then a CFL bulb accompanied by the text, "MAKE A CHANGE".

The video transitions to the youth engaged in a light bulb audit as they visit the bathroom of their school to see how many CFLs versus incandescent light bulbs they can find. In between inspections, the youth infuse information about the number of watts used by incandescent light bulbs versus CFLs and playfully chastise their teachers for not being green. They discover that all but one bathroom had incandescent bulbs, helping set up their content storyline around how using incandescent lights requires more coal to be burned leading to environmental consequences of human action on climate change.

They explain how they were able to determine incandescent lights were less energy efficient by the heat they release and elaborate on the environmental effects. They situate the issue locally, reminding viewers that electricity for the city comes from burning coal. The video shows pictures of a strip mine as the song lyrics ask, "what have we done to the Earth?" The scenes alternate between the youth on camera continuing to tell the story of human impact on the Earth and images with text explaining how damage done from mining is not reversible. The youth pull in the problem of excess CO_2 being produced from the burning of coal as energy consumption goes up. The video places the onus on human actions but also offers a chance to the audience to remediate habits and be empowered to make a change. The next portion of the video uses images and text instructing the audience that they can make a change and that as the song suggested, "it's easy as 1,2, 3…A, B, C". A youth then explains the amount of money the school can save as well as how much CO_2 release can be prevented by switching light bulbs. The video closes with the scrolling text reviewing how incandescent light bulbs used more energy requiring more coal burning and CO_2 release that leads to global warming as the song played "I'm asking you to make a change".

Discussion of CSE Model

Asserting a CSE identity allowed the youth a platform in which to engage in scientific ideas and discourses while also offering students the freedom to work and be in their community in ways that mattered to them. Being a CSE was fashioned out of a hybrid discourse and practice that did more than blend the space of "science" with the space of the "personal/cultural." Analysis of our data further reveal several key points that help to flesh out the CSE model.

First, and perhaps most importantly, becoming a CSE involves the iterative development of **vertical** and **horizontal** expertise, or in other words the development o knowledge and practices central to the science investigation at hand (vertical) and an ability to leverage that expertise in culturally responsive and agentic ways across the communities of practice in which the youth live, learn and play (horizontal). Developing and leveraging both forms of expertise fosters the novel authoring of hybrid discourses and practices that give science particular local significance (see Figure 3).

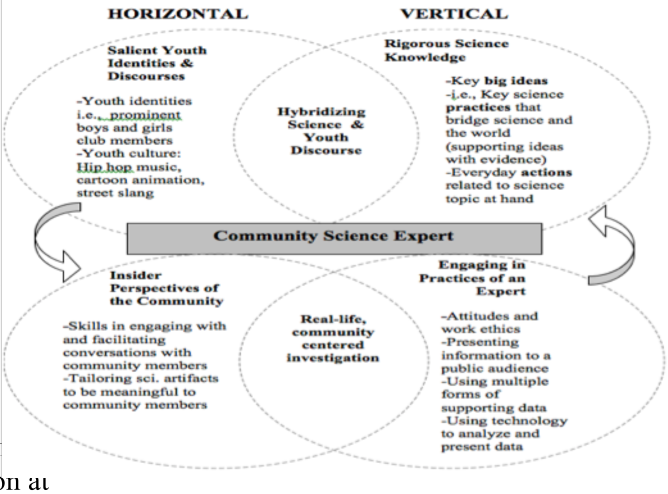

Figure 3: Vertical and Horizontal aspects of the CSE model

Central components to vertical learning include: a.) developing understanding of core science ideas, b.) developing a fluency in science practices that help link those ideas to the real world, such as learning to reason and argue with evidence in persuasive ways, and c.) developing multiple ways of representing ideas in science in both qualitative and quantitative ways. Central components to horizontal learning include: a.) making sense of how scientific issues matter in the community & making sense of how community concerns set up or frame specific scientific problems, b.) leveraging cultural knowledge and practices in ways that make scientific ideas accessible to broader audiences, c.) generating science artifacts that appropriate knowledge and practice in locally meaningful ways.

Second, becoming a CSE involves **making science accessible** to others by situating scientific talk and thinking within the work a day lives of ordinary people, and by orienting the doing of science towards taking personal responsibility and action. In Jana's Make a Change video, she and her peers draw upon their knowledge of how the failure of individuals to use energy efficient light bulbs is connected to detrimental environmental impact, by mining for coal and by the burning of coal releasing greenhouse gases. She situates her explanation of the impact of energy use on the environment through narration, images, music and text, she also uses the light bulb audit of their school to ground their message in the community and begins to develop the story of how the personal choices have consequences – i.e., "save the school money". Part of making ideas accessible required a **localized knowledge** of the scientific phenomenon at hand. For example, carbon cycling is a big idea (and an abstracted idea) in science, and yet, to be a make-a-difference expert meant that Jana could explain its value in terms that made sense scientifically as well as contextually to their schoolmates,–by "changing watts to dollars."

Third, becoming a CSE involves a process of **re-inscribing symbols**, **of youth culture** (verve, playfulness, boisterous, etc.) as *necessary elements* of scientific expertise, **of science** as a *valuable commodity* within urban youth culture (Calabrese Barton & Tan, 2010a), and of **work in the community** as evidence of hard working, capable youth. Youth in this project face the stigma of being "club kids," which, in their community, is code for "poor and black." By enacting science expertise that draws upon hip-hop, youth-speak, loudness, art and creativity alongside traditional scientific practices, they co-opted undesirable meanings of being a "club kid" with an urgency to build a more just world, fashioning a practice that was respected across different worlds (e.g., peer culture, white corporate culture). Legitimized by peers *and* authority figures (e.g., the mayor's office), such maneuvering positioned science as relevant to the community and youth as smart and cool.

We believe the re-inscription of symbols is important as it allows youth to make problematic some of the master narratives in science that have been constructed (primarily in school science but not necessarily in the 'real world' of science) as being in opposition to their everyday lives in terms of a.) what it means to be scientific; b.) what it means to engage in scientific communication; and c.) how one can be both a producer and critic of science. With their science documentaries, the youth problematized common symbols in science (or things that carry symbolic meaning) and in so doing, turned their meanings around towards their own purposes. One of the symbols the youth critiqued and transformed involved the ways scientific ideas were communicated and represented. Scientific language, in schools, is often rendered as dense, technical, and abstract. The abstraction of science works especially to obscure concrete life experiences into conceptual entities and generalizations. In Make a Change, we see that the youth instead, chose to specifically place their scientific ideas in context and to situate the meaning of their knowledge claims, rather than to represent ideas removed from context. We also believe that such re-inscription is important because it works to unsettle the dominant narratives that unfairly suggest that lower-income youth from African American communities do not care about science or the environment or are not hard working, and opens up new possible pathways for youth to pursue STEM trajectories.

Scholarly significance

Learning science is imperative for informed citizenship and opens possibilities for affecting one'community. Yet, statistics predict that the urban, low-income, minority students are unlikely to access quality science education. This white paper offers a model for youth engagement in science based on 5 design principles that helps us understand how urban youth already engage in complex sets of practice at the intersections of culture, place, and science, and which frame what it means to become an engaged expert in science.

A contributing factor that led to the youth's authentic and sustained engagement with green energy science issues at GET City is a highly supportive environment provided by mentors from engineering, science education, and local institutions related to green energy issues, such as the Board of Water and Light. Mentors working closely with the youth on a weekly basis not only provided youth with expert knowledge resources, but more importantly, enabled the youth to engage in both scientific and socio-scientific investigative practices alongside experts who actively solicit and encourage their participation. Engagement in such a manner with mentors from various stakeholders in green energy technology issues empowers youth as *they* are repeatedly positioned as legitimate stakeholders as well in the discourse of local green energy technology concerns. Such an empowering position and identity no doubt fostered youth engagement in GET City, paving the way for their authoring of a CSE identity. Implications from our study include:

1. How do we recruit, increase, and sustain the number and (relevant) diversity of mentors for youth in such programs on a long-term (GET City is 3 years and running) basis?
2. How should mentors negotiate between sharing their expertise while encouraging youth participation in ways that address the development of both horizontal and vertical expertise in science issues?
3. What pedagogical practices are especially efficient for mentors to facilitate the authoring of positive identities in science for youth that are traditionally disenfranchised?

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Youth STEM Motivation:
Immersive Technologies to Engage and Empower Underrepresented Students

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There is no learning without engagement, a situation that happens all too often in our typically lecture-based classrooms. At the same time, engagement without learning, which frequently happens in today's digital worlds, is not a healthy alternative. Some claim that online gaming is one answer to engaging and motivating students in their academic work. Yet, students can frequently be engaged in these virtual worlds without actually learning anything or being more academically motivated.

In this white paper we describe a project underway at Harvard's Graduate School of Education in which we are designing innovative technological environments that draw from theories of motivation to support and augment the engagement and motivation of students in Grades 5-8 mathematics. First, we outline Bandura's (1986) social cognitive theory. Next, we describe facets of our project that utilize this theoretical framework. Finally, we describe areas for further research and pose questions with the hope that they stimulate productive discussion among the scientific and educational community.

Social Cognitive Theory

Social cognitive theory is rooted in a view of human agency in which individuals are agents proactively engaged in their own development and can make things happen by their actions. They are "partial architects of their own destinies" (Bandura, 1997, p. 8). Key to this sense of agency is the fact that, among other personal factors, individuals possess self-beliefs that enable them to exercise a measure of control over their thoughts, feelings, and actions, that "what people think, believe, and feel affects how they behave" (Bandura, 1986, p. 25). Bandura (1986) provided a view of human behavior in which the beliefs that people have about themselves are critical elements in the exercise of control and personal agency. Thus, individuals are viewed both as products and as producers of their own environments and of their social systems. Because human lives are not lived in isolation, Bandura expanded the conception of human agency to include collective agency. People work together on shared beliefs about their capabilities and common aspirations to better their lives.

Rooted within Bandura's social cognitive perspective is the understanding that individuals are imbued with certain capabilities that define what it is to be human. Primary among these are the capabilities to symbolize, plan alternative strategies (forethought), learn through vicarious experience, self-regulate, and self-reflect. These capabilities provide human beings with the cognitive means by which they are influential in determining their own destiny.

Self-Efficacy Beliefs

Of all the thoughts that affect human functioning, and standing at the core of social cognitive theory, are *self-efficacy* beliefs, which can be defined as the judgments that individuals hold about their capabilities to learn or to perform courses of action at designated levels (Bandura, 1997). These self-beliefs touch virtually every aspect of people's lives—whether they think productively or self-debilitatingly; how well they motivate themselves and persevere in the face of adversities; their vulnerability to stress and depression; and the life choices they make. High self-efficacy also helps create feelings of serenity in approaching difficult tasks and activities. Conversely, people with low self-efficacy may believe that things are tougher than they really are, a belief that fosters anxiety, stress, depression, and a narrow vision of how best to solve a problem. As a consequence, self-efficacy beliefs powerfully influence the level of accomplishment that one ultimately achieves (see Pajares & Urdan, 2006 for a review).

How Self-Efficacy Beliefs Are Created

According to Bandura (1997), individuals form their self-efficacy beliefs by interpreting information primarily from four sources. The most influential source is the interpreted result of one's previous performance, or *mastery experience*. Individuals engage in tasks and activities, interpret the results of their actions, use the interpretations to develop beliefs about their capability to engage in subsequent tasks or activities, and act in concert with the beliefs created. Outcomes interpreted as successful raise self-efficacy; those interpreted as failures lower it.

In addition to interpreting the results of their actions, people form their self-efficacy beliefs through the *vicarious experience* of observing others perform tasks. Watching others solve challenging problems and overcome obstacles, for example, can help individuals to believe that they too can solve similar problems and overcome obstacles. Schunk and his colleagues have shown that *coping models*—those who struggle through problems until they reach a successful end—are more likely to boost the confidence of observers than are *mastery models*—those who respond to mistakes as though they never make them (e.g., Schunk, 1987; Schunk & Hanson, 1985, 1989). Coping models are especially effective for individuals who have difficulty learning, as competent people may perceive themselves as more similar to mastery models. For example, struggling math students who watch a peer model struggle through problems but who is eventually successful gain much more cognitively and motivationally than if they watch peer models effortlessly solve problems with no mistakes.

Social modeling is especially powerful when people observe a model whom they believe possesses similar capabilities as they do. Observing similar others succeed can raise observers' self-efficacy and motivate them to perform the task if they believe that they, too, will be successful. Hence, observing the successes of such models contributes to the observers' beliefs about their own capabilities ("If they can do it, so can I"). Conversely, watching models with perceived similar capability fail can undermine the observers' beliefs about their own capability to succeed (Schunk, 1987).

Model similarity is most influential for those who are uncertain about their performance capabilities, such as those who lack task familiarity and information to use in judging self-efficacy or those who have experienced difficulties and hold doubts (Bandura, 1986; Schunk, 1987; Schunk & Meece, 2006). When people perceive the model's capability as highly divergent from their own, the influence of vicarious experience is greatly minimized. It bears noting that people seek out models who possess qualities they admire and capabilities to which they aspire.

Individuals also create and develop self-efficacy beliefs as a result of the *social persuasions* they receive from others. These persuasions can involve exposure to the verbal judgments that others provide. Persuaders play an important part in the development of an individual's self-beliefs. But social persuasions should not be confused with knee-jerk praise or empty inspirational homilies. Effective persuaders must cultivate people's beliefs in their capabilities, while at the same time ensuring that the envisioned success is attainable. And, just as positive persuasions may work to encourage and empower, negative persuasions can work to defeat and weaken self-efficacy beliefs. In fact, it is usually easier to weaken self-efficacy beliefs through negative appraisals than to strengthen such beliefs through positive encouragement.

Physiological and emotional states such as anxiety, stress, arousal, and mood states also provide information about efficacy beliefs. People can gauge their degree of confidence by the emotional state they experience as they contemplate an action. Strong emotional reactions to a task provide cues about the anticipated success or failure of the outcome. When individuals experience negative thoughts and fears about their capabilities, those affective reactions can themselves lower self-efficacy perceptions and trigger additional stress and agitation that help ensure the inadequate performance they fear.

Overview of the Project: Transforming the Engagement of Students in Learning Algebra (TESLA)

The overarching goal of this research project is to investigate the relationship between specific technology-based activities and students' motivation in math and interest in pursuing STEM careers along a developmental span. To facilitate this research, we are developing a four-day, classroom-based experience for students in Grades 5-8. After the administration of measures connected to our research, the first stage of this experience is a one-day induction activity, where the students will participate in one of three technology activities. In the second stage, during a two-day mathematics lesson, students will explore mathematical patterns. Students will spend the final day by participating in the technology activity again to conclude the experience. Students will then complete measures connected to our research immediately after and roughly six months after the experience. By varying the technological context of the induction and closing experience while holding the instructional component constant at each grade level, and by measuring motivation constructs before and after the experience, we can test a series of specific hypotheses relating outcomes of interest (such as value beliefs, competence beliefs, STEM career interest, and mathematics learning) to activity assignment within grade.

With the above overview in mind, the following research questions guide our project: What is the impact of the 4-day curriculum on students' math motivation, interest in pursuing STEM careers, and math achievement? To what extent is this impact influenced by factors such as the type of induction the students received and/or students' demographic and academic characteristics (e.g., gender, race/ethnicity, prior achievement)? And to what extent is this impact influenced by teacher-level factors such as teachers' mathematical knowledge for teaching, credentialing in mathematics education, undergraduate major, years of experience, and teachers' beliefs (e.g., teaching self-efficacy)?

Research Design

The Technology Inductions

The capacity of humans to think symbolically and to learn vicariously positions technologies like virtual environments as a potentially important tool to bolster the motivation of students in math (Chen, Dede, & Zap, *in press*). To do this we are designing three contrasting types of inductions to integrate with a 2-day mathematics curriculum unit, based on 1) student immersion in a virtual environment, 2) web-based, teen-friendly, interactive modules that teach a Growth mindset, and 3) educational videos. Figure 1 shows screenshots of each induction. We are contracting with a team of computer programmers to help design and develop the immersive virtual environments. By collaborating with them, our team of math educators and motivation researchers are able to weave the specific math content and motivational goals into the immersive environment. Because our goal is not to teach students the mathematics before they get to their math lessons, this environment has been designed to be exploratory by nature—students explore the world, try their hand at the mathematical patterns, and begin to form some initial conceptions about how mathematical patterns might work.

With regard to the second induction, we are working with researchers and developers of a web-based interactive module that teaches students about a Growth mindset—the harder you work, the more capable you become. These modules are based on the work of Carol Dweck and her associates, which have been shown to be quite successful at influencing students' motivation and achievement over a developmental trajectory (e.g., Blackwell, Trzesniewski, & Dweck, 2007).

Finally, with regard to the third induction, because we wanted to create an experience that would be legitimately used by teachers, and that might represent what a typical teacher might do to generate some interest in mathematics, we decided to use a PBS NOVA video that explores patterns. The video, entitled *Search for the Hidden Dimension*, explores the fascinating phenomenon of fractals and how they are used in everyday life such as building Smartphone antennas and generating visual effects in movies.

Because the bulk of our efforts have been spent in designing and developing the first induction, we focus our discussion on the virtual space environment. How were theories of motivation used in designing this induction? Recall that self-efficacy is built primarily from the four sources of self-efficacy. In tapping the first (and most powerful) source of self-efficacy—mastery experiences—commercial games already provide the scaffolding and "leveling up" designs that are helpful in building students' beliefs in their ability to succeed. Each of the four locked doors that students must pass through is a "leveling up" experience signaling to students that they have just finished a particular puzzle, and that they are now moving on to a more difficult one. As students attempt to figure out the patterns that arise in these puzzles, the environment provides mathematically appropriate scaffolds that help students, but only if they get stuck during the problem-solving process. Because this activity takes place during the first day of a 4-day intervention whereby students are exposed to the motivational activity on day 1 and then take part in an in-depth teacher-led mathematics lesson on the second and third days, this technology activity is designed to provide students with the belief that they can, in fact, succeed in learning to solve the mathematical patterns that they will face later in the intervention.

A potentially powerful and somewhat understudied aspect of the virtual environment we are designing and building taps students' vicarious experiences. We have created short video interviews of real-life STEM professionals describing their experiences in learning math, and their subsequent path to a STEM career (see Figure 2). These young relatable professionals describe obstacles that they faced along their educational and professional paths and discuss the measures they took to overcome those challenges.

The message the professionals reinforce is that, with persistence and with the appropriate strategies, one can receive the training necessary to work in an exciting and rewarding career. The hope is that, because students are able to select from a number of young STEM professionals who are diverse in their occupations and outward physical characteristics (e.g., gender, race/ethnicity), students will be able to relate to one of these people and reap some motivational benefits. This design decision was made to address Bandura's contention that model similarity is an important component of what makes a model instructive. Because there is mixed empirical evidence about what constitutes model similarity, and because the literature on virtual models is scant, we hope our findings may help to illuminate which factors students consider when they select a STEM interview to watch.

As Bandura's (2001) and Sabido's (1981) work with telenovelas has shown, engaging television dramas can be created using vicarious models to instill large scale changes in human behavior. For example, soap operas were created to teach some communities about the value of furthering one's education, and provided viewers with information at the end of these shows to put them in contact with people and resources to help viewers achieve their educational goals. The popularity of such shows and the massive response of viewers in applying to educational institutions demonstrate the impact that interventions centered on vicarious modeling can have.

We believe that designers of technological environments can take a similar approach. Besides overt characteristics like gender and race/ethnicity, students may be looking for clues about how similar the model is based on perceived relative ability (i.e., "is this person about as smart as I am?") and on attitudes (i.e., "did this person feel somewhat ambivalent about mathematics just like I do?"). For this reason, we asked each interviewee to dress fairly casually and to not say anything that might suggest that this person is not relatable to the average middle school student.

We also asked the professionals to talk about what they did not like about math and any other challenges they faced that may have stood in the way of them becoming a STEM professional. For example, one interviewee described the fact that he grew up "dirt poor and Black." Besides the material things that such a situation placed him in, there were also psychological consequences of this, such as thinking that "college is for those well-to-do kids who don't look like me." This particular person described how he had to overcome that thought, with the help of his father who pushed hard for him to go to college, before he seriously considered both a college education and more specifically a career in math and science.

Prospective Findings

Data from this study (which have yet to be collected) will help inform researchers and instructional designers about which types of technology activities tend to benefit which types of students the most. On the one hand, the virtual space world allows students to actively participate in the mathematics to be addressed in the math lessons, and allows students to take on the identity of a space explorer. It is designed to target self-efficacy as well as value beliefs. On the other hand, the Growth mindset modules are not specifically tailored to the math lessons; do not allow students to take on the identity of someone; and target students beliefs about math intelligence. By comparing students in each condition, we can explore which student-level and teacher-level characteristics tend to be associated more with motivational and/or achievement gains in each condition. Moreover, because the third technology activity is a low-cost alternative that many educators are familiar with, and that has been used extensively in the past, we can explore whether the motivational and/or achievement gains of students were worth the cost to produce and deliver to a large number of students.

Future Directions and Questions for Discussion

We began this paper with the assumption that beliefs about competence are strong predictors of students' achievement in math and science and of their interest in pursuing STEM careers. However, beliefs about competence are not the only important motivation variables, nor are they always the strongest predictors. As Brophy (1999) has argued, there is a great need to study the value components of motivation as well. In fact, Brophy argued that, when it comes to motivation to do well in a particular subject or motivation to perform a specific task, competence beliefs might well be great predictors. However, when it comes to making larger decisions such as pursuing a STEM career, value beliefs may play a much more central role in students' motivation.

Therefore, steps should be taken to not only build adolescents' beliefs that they can succeed in math and science, but also to foster the sense that math and science are enjoyable (interest value), important to society (importance value), can help advance one's own educational, career, and personal agendas (utility value), and that the education and training are worth the time and effort (cost value). The question for researchers is how do we design and build technologies that can *meaningfully* and *authentically* foster these types of beliefs?

As Bandura (2001) and Sabido (1981) have shown, social cognitive theory can only provide the theoretical architecture on which actual products can be built. The next steps include the more micro level research involved in exploring the specific cultural milieus and motivational belief systems that researchers hope to influence. For example, if researchers wanted to design and build technology activities targeted to rural poor students in the Southeastern US, there are cultural milieus that would no doubt greatly influence the types of vicarious models to use. These cultural milieus and belief systems are likely quite different from those of the urban poor in the Northeastern US.

Therefore, our basic assumption is that motivational activities are not a one-size-fits-all formulation. Rather, the technological activities that people design must be keenly attentive to the context of the targeted audience. These translational and social diffusion models, as Bandura has called them, are critical for motivation interventions to work. As a parallel, commercial video game designers are fairly attuned to their audiences when they design, build, and sell their products. For example, the FIFA soccer video games feature actual FIFA club teams and players with whom users can readily identify. Also, the cover of the video game changes depending on the country in which it is sold—in the United Kingdom, British players are featured, whereas in Italy, Italian players are featured.

As another example, any games, such as World of Warcraft, take the approach of including many motivational design decisions that are bound to be useful for someone. For example, World of Warcraft includes exploring a virtual world and seeing very visually stimulating landscapes, which may be motivational for some. Others may be motivated by the combat features of the game. Others may be motivated by buying and selling at auctions. And still others may be motivated by the social aspect of meeting, talking with, and going on adventures with either friends or other online users from around the world. In the context of educational settings, and more specifically, in the context of math and science motivation, how might designers and researchers decide on which route to take—the "kitchen sink" approach like World of Warcraft, or the context sensitive approach similar to what Sabido and Bandura described for their television dramas?

Technology activities designed to motivate students in math and interest them in STEM careers may need to take similar approaches. The reason why, many times, such efforts do not take place is likely because of time and money. But can motivational inductions succeed with a broad audience unless sufficient time, effort, and money is spent to do so?

In addition to value beliefs, according to Ryan and Deci (2000), relationships are also important in motivation—students tend to be more motivated when they feel a sense of belongingness and connectedness in the activities in which they are involved. As was evidenced by the television dramas created by Sabido, a key component of effecting change in people's behaviors and beliefs was providing contact information for viewers to receive more information about how to change their lives.

Innovative technologies possess considerable power in their ability to connect people around the world in an instant. Struggling students, especially those who are traditionally underrepresented in STEM fields, would likely benefit from feeling a sense of connectedness and belongingness. Social networking tools and immersive virtual environments are potentially useful tools that can aid in connecting disadvantaged students to vicarious models or organizations that can facilitate students' entry into STEM fields.

But how can these tools be effectively utilized in educational contexts? How are the relationships that are formed digitally different from the ones that are formed in person? And how might these differences be meaningfully addressed to motivate students in math and science and engage them in STEM fields? These are important questions for design-based research.

Finally, as mentioned earlier, students do not live their lives in isolation. Therefore, in addition to self-efficacy beliefs, *collective* efficacy may play an important part in motivating students in math and science. Again, this is especially likely with students who have been traditionally underrepresented in STEM fields. A recent example illustrating the power of collective efficacy is how youth revolts that began in Tunisia started an uprising across the Middle East. These revolutions were able to take place, to some extent, because of emerging technologies. How might technologies in educational contexts be designed to empower disadvantaged students to believe that they too can attain meaningful careers in math and science?

Conclusion

Technology cannot solve all of our problems in STEM motivation. As a tool, it is only as good as its creators' designs. As a teaching tool, immersive technologies still have a long way to go with regard to what constitutes "best design practices." As a *motivational* tool, they also have quite a long road ahead of them. Our hope is that this paper provides one piece of the puzzle to creating motivationally sound immersive technologies by outlining a useful theoretical framework on which to build. The real work now begins by exploring the translational and social diffusion models that can further the goal of motivating students in math and science, and boosting their interest in pursuing STEM careers.

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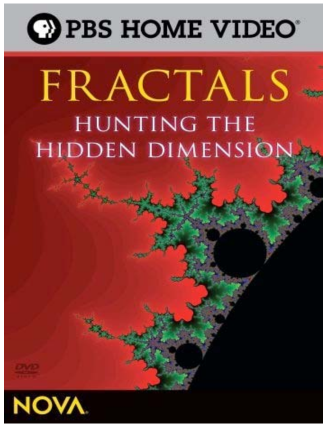
Figure 1. Screenshots for Each Induction

Induction 1: Virtual Space World

Induction 2: Growth Mindset Web Modules



Induction 3: Video

Figure 2. Interviews With STEM Professionals

Title: Motivation and Culturally Responsive Technology for COMPUGIRLS

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Problem Statement

Explanations for why girls from underrepresented groups (e.g. African American, Hispanic, and Native American) do not enter and/or persist in STEM fields in general and technology disciplines in particular, consider a multitude of factors. Among the suggested reasons, lack of motivation continues to shape much of the discourse and programmatic efforts. Although we come from different disciplines (social justice studies and educational psychology) our training and individual research, as well as our combined efforts on the COMPUGIRLS project have provided us with significant evidence that the above description is a misrepresentation of our girls' lived experience and the motivational psychological constructs often cited as part of this discussion. Specifically, we argue that the taken-for-granted view of motivation is problematic for two reasons.

Motivation and Self-Concept

First, it is commonly believed that motivation is an innate construct. Such a perspective describes motivation as an immutable entity that some individuals inherently lack. In contrast, some education psychology research maintains that motivation is a process related to future beliefs (Oyserman & James, 2009), self-concept (Marsh, Gerlach, Trautwein, Lüdtke, & Brettschneider, 2007), and self-efficacy (Usher & Pajares, 2006). Of these three motivational beliefs system all are highly influenced by context, and amenable to change – in some cases very rapid change.

The concept of "the self" is central to social and educational psychology. The self not only represents what we know of ourselves from our past experiences, but also holds what we expect from ourselves in the future (Husman & Lens, 1999; Markus & Nurius, 1990; Nuttin & Lens, 1989). The study of humans understanding of themselves in the present, and in the context of educational achievement has been dominated by Herbert Marsh and his colleagues (Marsh & Craven, 2006; Marsh, Gerlach, Trautwein, Lüdtke, & Brettschneider, 2007; Marsh, Tracey, & Craven, 2006; Marsh, Trautwein, Lüdtke, Köller, & Baumert, 2006). Much of this research has focused on the validation of the Academic Self Description Questionnaire II as a high quality measure of domain specific self-concept (Marsh, 1990). Marsh has successfully used this measure with adolescent students from various academic and personal backgrounds. Due to the widely known success of this measure, and its domain specificity we chose to use this instrument to measure our students' academic, technological, and general self-concepts; and to track changes in their self-concepts over time.

One aspect of students' motivation for engagement in the present and the future is their understanding of the connection between present behaviors and future goals. This connection has been called Perceptions of Instrumentality, the perception that some tasks are instrumental to achieving important future goals. Perceptions of Instrumentality have been shown to influence students' achievement, motivation, and learning (Husman, Derryberry, Crowson, & Lowmax, 2005; Turner & Schalertt, 1999). We were interested to find out how instrumental adolescence girls' of color beliefs of learning technology was for their future goals. We also wanted to know how instrumental the students found working on the types of projects we provided. To measure student's perceptions of instrumentality we used a measure which has been used frequently and successfully with late (Turner & Schallert, 2001) and early (Van Calster, Lens, & Nuttin, 1987) adolescences.

Another aspect of humans' projection of themselves into the future has been researched in adolescence in high-needs areas under the description of Future Possible Selves (Oyserman, Brickman, & Rhodes, 2007; Oyserman & James, 2009). Oyserman and her colleagues have successfully used the Academic Possible Selves measure to examine the possible selves of students from high-risk, high-poverty areas in the Detroit metro area(Oyserman & Fryberg, 2006). We chose to use her measure both because of the strong validity and reliability evidence, but also because we felt the measure would provide us with the greatest amount of information about the future expectations of the students in our study.

Students' expectations of their future selves and their perception of their current selves greatly influence the value students have for activities (both academic and non-academic). Although critical to engage students and encourage them to value STEM activities (in formal and informal settings), students who value an activity but doubt their ability to successfully reach their goals or perform in those tasks may (often referred to as self-efficacy) create a situation where they experience high anxiety and negative emotions. This situation is likely to result in disengagement in their value of the activity (Brophy, 2002). It is therefore important not only to track students' understanding of themselves but also their understanding of their self-efficacy for completing the specific STEM activities involved. In our case we were concerned that students feel competent doing computer and web-based activities. We used the Computer Interface Literacy Measure (CILM) (Turner, Sweany, Husman, 2000) which assesses students' self-efficacy for specific computer knowledge and skills as well as functions as an objective measure of their computer literacy. For our task we updated the CILM to emphasize the software and operating systems currently in use.

Within this understanding of motivation lies the argument shaping our efforts: The earlier youngsters receive nurturing experiences and frames that support particular adaptive motivational beliefs, the greater the likelihood for strengthening their future beliefs, self-concept, and self-efficacy. To deeply influence these self-beliefs and produce an effective process, we argue that these experiences need to be culturally relevant and resonate with the students' deeply seated understanding of themselves in relation to their community. Although this notion is rarely considered when examining disadvantaged populations, it leads us to our next critique.

Motivation in Cultural Contexts

Second, believing that students from high needs areas lack motivation too easily recalls the cultural deficit model (Solorzano,1991, Valencia, 1997). Often used to explain the achievement gap, cultural deficit thinking faults students' culture, motivation, and/or community for preventing academic success rather than noting the structural, institutionalized constraints impeding true progress. Similarly, some researchers and program developers maintain that certain population's lack of technological motivation is due to their community's lack of interest or belief in digital media. When such contexts do use technology, their employment is often marginalized or rarely valued (Everett, 2009). Such communities' purported technophobia (Monroe, 2004) leads to structural and individual implications. Contending that underrepresented groups' cultures preclude its individuals from being motivated and interested in technology allows high needs schools to not offer advanced technology classes (Goode 2007; Margolis, Estrella, Goode, Holme, & Nao, 2008), and a proliferation of enrichment programs that are culturally irrelevant (Scott, Aist, Hood, 2009; Scott, Clark, Sheridan, Mruczek, & Hayes, 2010). Culturally relevant practices (CRP; Howard, 2003; Ladson-Billings, 1995; Milner, 2010; Lee, 2007; Gay, 2002) stand in direct opposition to these beliefs and actions.

CRP maintains three key features**:** 1) Asset Building: a youngsters' cultural knowledge is an invaluable asset that should shape the learning process; 2) Reflection: Instructors involved in the learning process need to reflect upon their own positionality challenging what they know and how they gained knowledge about people and content; and 3) Connectedness: Students should feel that their learning should and can affect their communities insofar as they feel a sense of responsibility to something larger than themselves (i.e. peer group, community, ideals).

In combination with our understanding of motivation theory, we constructed COMPUGIRLS (NSF # 0833773) around the following assumptions: Although girls from high needs districts may not have access to mastery experiences or digital media that is culturally relevant, they may be highly motivated to interact with multimedia if provided the opportunity. The effects of such an opportunity will be more pronounced in a digital media experience that incorporates the above elements of culturally responsive practices. Programmatic implications of these assumptions caused us to create COMPUGIRLS as a six-course, culturally responsive, multimedia after school and summer program aimed at adolescent girls (ages 13-18) who rarely if ever have exposure to culturally relevant digital media.

The PI worked primarily with two Phoenix-metropolitan school districts to recruit a cohort of 40 girls to navigate the two-year program. Upon receiving over 100 applications, 50 girls were selected to participate based on their essay scores. The vast majority of the girls are Hispanic (76%) followed by a significant percentage of African American female participants (16%). During the Summer 2009, participants began the first COMPUGIRLS course at Arizona State University's Downtown Campus. This paper examines their future time perspective, self-concept, and self-efficacy during the first three courses.

Although the media product of each course varied, dependent upon the used software, two end results remained constant—a research paper and a digital media presentation of their results. Throughout the courses, carefully trained mentor-teachers led small and large group lessons around issues of social justice, software and hardware use, and the role of technology towards community advancement. Meetings required individuals to continuously reflect upon self-selected topics; consider how digital media could be used to answer the individually created research question; and analyze the results and ultimately present the findings while discussing implications to various audiences. The curricula encouraged the girls to demonstrate to their peer group their strengths (assets) by requiring girls to provide progress reports, verbally articulating what they learned, and posting ideas using Ning. Instructors were encouraged to monitor the girls' demonstrations, document them, and incorporate their cultural knowledge into subsequent lessons. Often this led to peer mentoring, girls presenting how they accomplished tasks, and interdependent group work integrated into lessons. From these exchanges, girls learned how to provide feedback to their peers. Importantly, as participants' became more connected with each other, instructors and girls' co-created rules, adjudication systems, and peer feedback loops. At the conclusion of each meeting, we required girls to reflect upon and share their progress, articulate short and long-term goals, and direct recommendations for future accomplishments. Equally important, each course concluded with a community-wide celebration organized by participants. At these events, girls showcased peer-selected projects to family, friends, school administrators, community advocates, and university affiliates.

Method

Participants

To contextualize our results, we created a matched comparison group. Based on work by staff and district personnel within the Roosevelt Elementary School District and the Phoenix Union High School District, the project PI worked closely with school and district level administrators to develop a procedure for identifying participants and administering the surveys. In Roosevelt, for instance, an assistant principal worked with the computer lab instructor to disseminate permission slips and arrange for the survey administration days and times. The students were allowed to come to the computer lab during a two-hour block and complete the surveys. Evaluation staff were on hand immediately or at a pre-arranged time to have students complete a compensation form receipt and to receive a $5 gift card. Two Phoenix Union High School District administrators (technology department and research department) worked together to develop the protocol for their survey administration. The technology administrator identified one key staff at a number of campuses who would be in charge of working with the evaluation team to recruit students and administer the survey. The high school district staff requested copies of all permission slips.

The arrangements for comparison group participants were not completed by summer, so their first survey administration occurred in conjunction with the fall administration for COMPUGIRL participants.

The analysis employed for the two groups was a two-way ANOVA with unequal sample sizes. This was used to evaluate the effects of two groups (COMPUGIRLS and comparison group), and time on the dependent variables PS, ASDQ-SC, ASDQ-TS, and CILM. To account for the differential in survey times, the analysis included the first and fourth semester results on the dependent variable for both groups.

The time periods used were the following:

- Time 1= First Semester
- Time 4= Fourth Semester

For COMPUGIRLS participants, that translates into Time 1 being their pre-summer 09 and Time 4 being their Post-fall 09 scores. For the comparison group, Time 1 is pre-fall 09 and Time 4 is their post spring 10 scores.

The COMPUGIRLS participants and members of a comparison group completed one or two rounds of surveys in 2009. The table below lists the total number of participants, by group, within each survey administration.

Table 1: Number of participants by group

Group	Pre Sum 09	Post Sum 09	Pre Fall 09	Post Fall 09	Pre Spring 10	Post Spring 10
COMPUGIRLS	**43**	**37**	**31**	**29**	28	23
Comparison Grp			**61**	**52**	44	39

Measures

Possible Selves & Plausible Strategies Questionnaire

This instrument was administered for the students to express *Expected Selves* ("next year, I expect to be…") and *Feared Selves* ("next year, I want to avoid…"). Additionally, the instrument asks if she is doing anything to accomplish this goal, and if yes, identify what she is doing now to facilitate this. Each survey is scored by 2 raters who coded the questionnaires for academic plausibility. The questionnaire author, Daphna Oyserman explained that "plausibility is meant as a general assessment of the usefulness of the achievement related visions and strategies the student describes as a 'road map to achieving in school' or a plan of action." (Oyserman, et al., 2004) Plausibility scores range from 0 (none or a single, vague academic possible self) to 5 (multiple academic possible selves and strategies that focus on both the academic aspects and social interpersonal aspects of attaining the academic goal).

Perceptions of Instrumentality Scale

The Perceptions of Instrumentality Scale (PI) (Husman et al., 2005) asks the students if they would use what they learned in the COMPUGIRLS program in the future and that the skills and information will be important to their future success. It was only used in the CG survey. The response categories ranged from *strongly disagree* (1) to *strongly agree* (5) Reported Cronbach's alpha =.86.

ASDQII

Three of the subscales from Academic Self Description Questionnaire II (Marsh, 1992) were utilized: Computer Studies/Technological, Stable Personal Preferences, and Academics. The ASDQII instrument measures multiple subject matter dimensions of academic self-concept and is designed for use with early adolescents. Reported coefficient alpha estimates of reliability varied from .89 to .95 for the scales.

Computer Interface Literacy Measure (CILM)

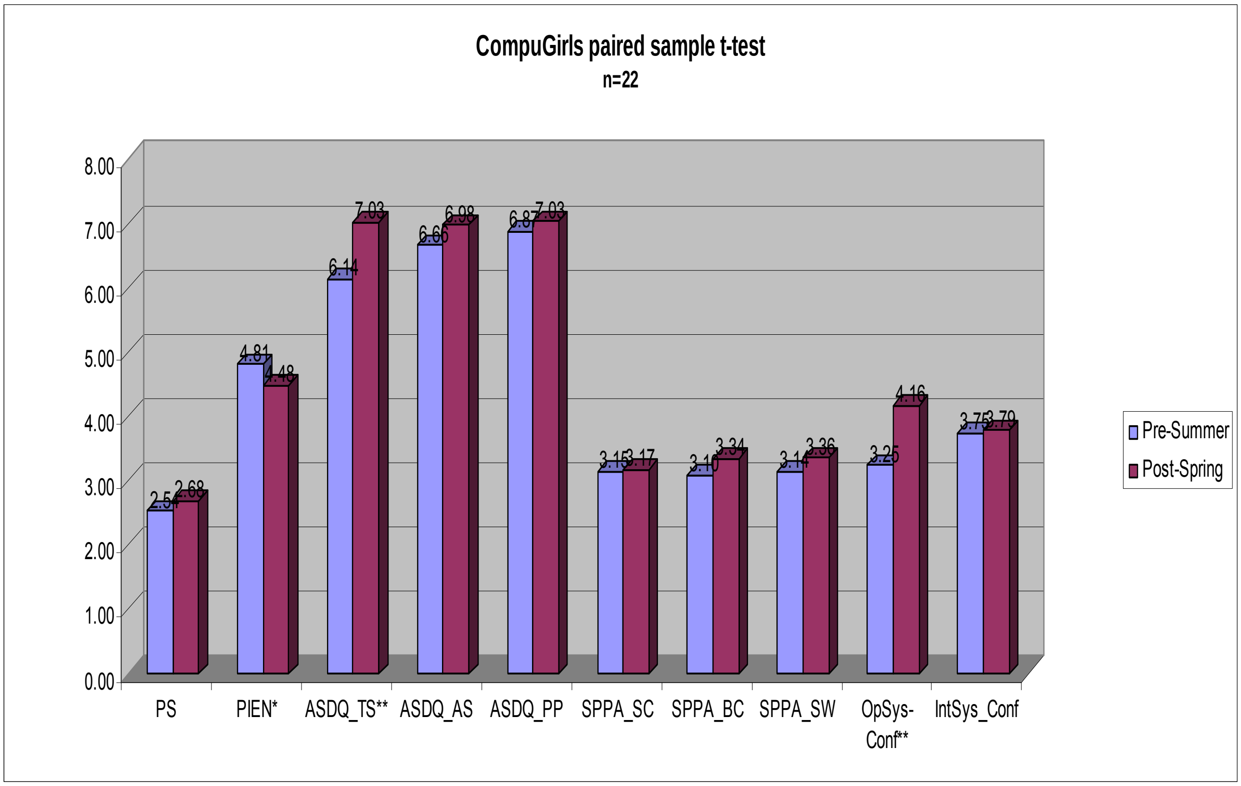
To measure participant change in technological skills, the CILM Measure (Turner, et al., 2005) survey was used. The items measured included confidence in using operating systems, skills and knowledge in using operating systems, confidence in internet use, and skills/knowledge in using the internet. The CILM is composed of both self-report (26 items α=.90) and knowledge application subscales (42 items; α=.85).

Results

In order to examine growth for the COMPUGIRLS participants, a paired sample t-test was conducted using the pre-summer to the post-spring scores on all commonly repeated measures. This included ASDQ, SPPA, PS, PIEN, and CILM measures.

COMPUGIRLS												
	Sum Pre Survey		Sum Post Survey		Fall Pre Survey		Fall Post Survey		Spring Pre Survey		Spring Post Survey	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
PS	2.36	1.495	2.92	1.26			2.79	1.264			2.61	1.12
PIEN_M	4.60	.54138	4.77	.328	4.7016	.350	4.62	.456			4.49	.576
ASDQ_TS_M	6.23	.97562	6.31	1.153	6.7073	.983	6.79	1.071	7.04	.869	6.95	.851
ASDQ_SP_M	6.81	.77230	6.86	.878							7.03	.801
ASDQ_AS_M	6.55	.92286	6.65	1.11			6.87	.913			6.98	.586
OpSys_Conf	3.25	.49461	3.90	.558			4.07	.356			4.15	.349
Internet_Conf	3.77	.43581	3.87	.387			2.73	.296			3.8	.381
	N = 41		N = 32		N = 31		N = 29					

The Perception of Instrumentality (significant decline p < .05). The growth in ASDQ-TS and Operating System Confidence was statistically significant (p<.001).

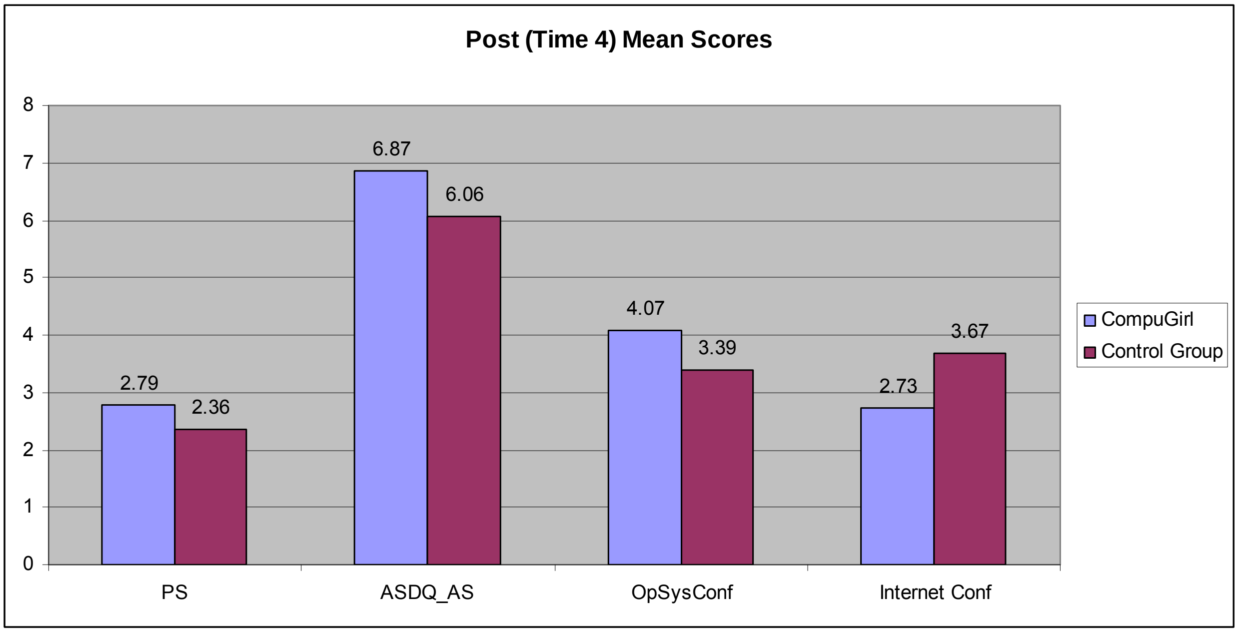


Note: n=22 *p < . 05; **p < .01

Comparison Group and COMPUGIRLS

The ANOVA results reveal a significant interaction on a few measures between the groups (COMPUGIRLS, comparison) and Time of measurement on the possible selves measure and technological skills (operating system use confidence). Compared to the comparison group, the COMPUGIRL participants had higher scores in possible academic self-confidence and operating system use--scores that increased over time. However, the Internet use confidence measure was a significantly higher value for the comparison group over time.

Possible Selves (PS): *F* (1, 162) = 5.08, *p*<.05
CILM Internet confidence: *F* (1, 161) = 58.2, *p*<.001
CILM Ops Sys Use: *F* (1, 162) = 15.93, *p*<.001



A significant group main effect indicated that COMPUGIRLS tended to have greater academic self-concept and operating system confidence scores than the comparison group. The increase in average score between Time 1 and Time 4 was also significant for operating system use (p<.001).

ASDQ-SC: *F* (1, 162) = 7.38, *p*<.05
CILM Ops Sys Use: *F* (1, 162) = 15.93, *p*<.001

Discussion

The participants of the COMPUGIRLS participants did enter the program with less exposure to and confidence in their use of computers. The participants, however, did have strong stable self-concepts—that is, in general, they thought of themselves as strong capable girls. They did lack exposure to technology, however. Over the course of their participation in COMPUGIRLS, their technological self-concept grew, as did their academic self-concept, and their academic possible selves. The change in these scores was significantly greater than any change in the comparison group. This indicates that the participants' structured engagement with technology was significantly more than the girls' peers across the same period of time. Although, still less confident than their peers about their skills in working with the internet – the students' understanding of the selves in technology contexts did improve. We infer that students who lack exposure to technology and therefore lack confidence in their use of technology, can in a fairly short period of time, change how they see the role of technology in their own lives, and can develop a strong and healthy technological self-concept.

Our findings encourage three suggestions related to motivation, culturally relevant practices, and approaches to widening the pipeline for underrepresented girls.

Suggestion #1: Lack of exposure to mastery experiences and digital media do not necessarily translate into participants' self-concept as technophobic. Digital media enrichment programs may do well to initiate their efforts understanding that the populations they wish to serve do not necessarily see themselves as technologically or academically disadvantaged. The more immersed COMPUGIRLS became in the program and the more they interacted with technology they may have realized how much more they needed to learn. Interestingly, if this is the case, it did not affect their self-concept along other lines. Program developers need to consider that not knowing a concept may not deter such individuals but pique their interests in other areas.

Suggestion #2: In fact, curricula should draw on the participants' cultural knowledge positioning it as an asset seamlessly integrated into lessons. This requires a considerable amount of training for teachers and guidance for participants, as the approach is antithetical to most formal learning environments. Additionally, the lack of equal confidence in working with the Internet does not seem to depress the burgeoning confidence of seeing themselves as capable in other areas. For individuals in general, our self-concept includes how we perceive our identities over time and contexts. Elsewhere, we discuss how race, social class, and gender are significant features that shape identities for girls of color. Self-concept is fluid and mutable and culturally influenced. Capitalizing on this approach seems paramount.

Suggestion #3: Approaches need to be interdisciplinary. Combing educational psychology with concepts from social science (e.g. culturally relevant practices) provides much needed space for new approaches such as culturally relevant computing (Gilbert et al., 2009). Greater collaborations among researchers and practitioners need to be made when developing enrichment programs. Room needs to be left for modifications where participants' voices included in authentic ways.

Follow-up work should explore how these results change over time. Particularly after the sixth course when participants engage in a summer internship and apply their research and technology skills in a work setting, a longitudinal study could examine how their self-concepts develop in different contexts and the potential impact it may have on their selection of college majors.

In sum, COMPUGIRLS' participants may not have as much exposure to culturally relevant digital media but they are motivated and willing to engage in such a program even with limited understanding. Without sustained opportunity to a culturally relevant computing experience, we fear that the technology workforce will remain limited. Offering a culturally relevant computing experience seems to hold promise for diversifying the pipeline for how can one construct an idea of the future without identifying present possibilities?

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Motivating youth through authentic, meaningful and purposeful activities: An examination through the lens of transformative activist stance

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Abstract: An ongoing and at times seemingly intractable issue in science education and STEM fields is the underperformance and underrepresentation of marginalized youth. This is often attributed to disconnect between school in general, school science specifically and the cultures that youth enact and experience in their daily lives. Although research demonstrates that youth become engaged in STEM when it is relevant to their well-being and that of their community, the question of what motivates underrepresented youth to pursue STEM interests is still not fully understood. This white paper argues for framing program development, evaluation and research within a transformative activist stance. Such approaches give voice to youths' perspectives on how and why they participate in STEM programs, enabling the design of youth-centered STEM programs that more effectively develop and sustain interest in STEM careers and pursuits.

Problem

The National Science Board (2010) states the key to the nation's success is to invest in its human capital, particularly the next generation of STEM innovators. Towards that goal, they recommend that as a nation we "cast a wide net to identify *all* types of talents and to nurture potential in *all* demographics of students" (p. 3). We also know that in order for youth to succeed in the future workforce, they must be competent in 21st century skills (www.p21.org); specifically they need to be able to think creatively and critically, while also being able to communicate and collaborate.

Although an important goal to nurture the potential of *all* types of students, it is also tremendously challenging tall order since we face an ongoing and at times seemingly intractable issue of attracting youth from underrepresented communities into STEM fields (National Academies of Science, 2007). This is often attributed to disconnect between school in general, school science specifically and the cultures that youth enact and experience in their daily lives (Lemke 2001, Roth & Tobin, 2007). Although research demonstrates that youth become engaged in STEM when it is relevant to their well-being and that of their community (Connell, Halpem-Felsher, Clifford, Crichlow, & Usinger, 1995; Rumberger, 2004; Edelson et al. 2006), the question of engagement—what initially motivates underrepresented youth to become interested in STEM, and what contributes to sustained interest over time, is not fully understood.

Appreciating that motivation is a dynamic, situated, and domain-specific phenomenon, a process that can be inferred from observing youths' actions (Schunk, Pintrich and Meece (2008), we posit that youth-centered, goal-directed activities can increase underrepresented youth interest and engagement in STEM, while also building their 21st century skills. Goal-directed activities empower youth to respond to issues in dynamic, situated, and domain-specific ways. Merging this view of motivation with a transformative activist stance (Stetsenko 2008) of learning and identity development, we recommend that youth engagement activities emphasize participation in activities in which youth are simultaneously producing, reproducing and transforming others and themselves through the process, all with the goal of contributing to society in some small way. We find this approach to thinking about motivation and identity development useful because our central thesis is that youths' STEM motivation will increase if the OST programs in which they participate engage them in real-world activity and problems of consequence, positioning them to be generators of and contributors to the STEM enterprise, as well as contributors to society. Youth want to matter and belong and contributing to society is one way that youth can do so. Such contributions can include creating something to engage, excite or interest their peers or to improve the quality of life in their immediate community. What matters is that there is a goal that affects people beyond themselves.

The objectives of the paper are to 1) frame the development of ITEST project activities through the lens of transformative activist stance (Stetsenko, 2008) thus beginning a dialogue for how activities designed and implemented in this way can potentially motivate youth to develop long-term dispositions and identities as STEM practitioners and 2) describe how participatory research methodologies can be integrated into ITEST activities in ways that support both the goals of research and the implementation of more effective programming for youth.

We describe how a specific project engages a diverse group of high school students to participate in a meaningful, purposeful activity that allow students to exercise both STEM and 21st century workforce skills. We ground our work in socio-cultural perspectives because we recognize that learning is a social activity, mediated by institutional and cultural factors. We also recognize that learning, identity development and motivation occurs when people engage in activities that are meaningful and valued by themselves and others. The described project is considered a transformative activity because one not only engages in the process of learning—learning the collaborative practices of a community and finding their role in it—but also in the process of Becoming, which Stetsenko (2008) describes as, "[humans becoming] agents of their own lives, agents whose nature is to purposefully transform their world" (p. 12).

Methods

Increasingly many ITEST projects have a central component which positions youth to participate in meaningful, purposeful activities that contribute to the well-being of society, for example through environmental activities or by supporting others to develop an interest in and engagement with STEM topics. In such activities, youth play a major role in deciding how they will engage in STEM and what tangible products will result. We will describe and interpret one specific ITEST project, Virtual Hall of Science (VHOS), within the transformative activist framework, demonstrating how taking such a purposeful stance can motivate students to engage in STEM activities and potentially pursue and persist in STEM education and careers.

The Broader Context

Situated in one of the most diverse districts in the country, the New York Hall of Science (NYSCI) employs local youth to work as Explainers to facilitate learning interactions with visitors that allow them to explore scientific phenomena. This program directly addresses challenges of motivating young people in STEM by working with them through a graduated program that enables them to advance as they master STEM knowledge and skills required for them to take on increasing responsibilities. Explainers are recruited based on their interest in having a job, rather than on their academic performance. Often Explainers hired are initially somewhat shy, but they demonstrate an interest in working with people. Many even claim to dislike or be afraid of science when they begin their relationship with NYSCI. Over time, Explainers develop an understanding that they are part of a bigger endeavor and that their actions and activities matter to the success of the science center, and to the experiences of the school and family visitors. The Explainers are motivated to learn science and understand the exhibits because they want to be well versed in the content before they interact with visitors. Working at the science center has even motivated some to considered careers in STEM and teaching. The quote below shows evidence for how one student attributes her career to her experiences at the museum.

> I am who I am because of the Hall of Science; I wouldn't have the Masters degrees. I wouldn't have all this. My career choice is directly related, I wouldn't have been working in [a] science institution without the museum. When I go to interviews for science organizations, I'm able to walk in and show how much I know, and show I have the ability to learn what I don't currently know." [Female Asian American, 31-35, professional]

Explainers are learning both science content and constructivist-pedagogy as they continuously improve their mediating skills. They are also engaged as constructivist learners—continuously scaffolding new content and ideas as they build their expertise. Both individually and collectively, the Explainers create and recreate a distinct practice of teaching science on the floor at the Hall. The structures that exist in this OST setting—interactive exhibits, and supportive peers and supervisors—afford the resources for their learning and identity development. Their ongoing motivation for learning is to make a difference by becoming better facilitators. They also gain self-awareness of how they and others learn, also an important 21st century learning skill.

Virtual Hall of Science

In order to extend the success of the Explainer program, NYSCI designed the VHOS, to support students in developing not just their 21st century skills, but also their ICT skills. While the ultimate goal of VHOS is to encourage young people to consider STEM careers, the immediate goal is to engage them in using these skills to contribute to an activity that has purpose beyond the walls of the classroom. In the VHOS project, approximately 40 high school Explainers work closely with scientists, educators and other professionals (referred to as project leadership team) to develop the skills to conceptualize and create STEM exhibits in a 3-D space which populate a virtual science center. Their goal is to create entertaining science learning experiences for visitors of all ages. This space is not just a workspace for youth, but a “real” place that will be opened to the public where families and school groups can engage in the learning environment created by the Explainers. The students, both individually and collectively, contribute to the content of this space and are responsible for getting it ready for public use.

Working in groups of four, Explainers first decide the content they want to focus on. They learn how to design within the virtual world and then as they create prototypes of their interactives, they get feedback from their peers, from the NYSCI staff, from experts in the field of technology and museums. At key points throughout the project, Explainers have the opportunity to present face-to-face and virtual showcases to visitors to test the usability of their interactives. The Explainers learn both soft and hard work skills as they assume responsibility for each phase of the project. They are motivated by this responsibility because they know that the success of the visitor experience is in large part due to the quality of the experience they create.

Weaving Research into Practice

As stated earlier more recent social cognitive conceptualizations of motivation see it as a dynamic, situated, and domain-specific phenomenon (Schunk, Pintrich and Meece (2008), Such complexity creates challenges for the educational research community as they attempt to document the role of motivation. It is both difficult to determine the best ways to gauge motivation and to understand the many different factors that mediate what does or doesn’t motivate youth to become interested in participating in STEM activities. Some factors are even beyond the control of youth such as access to opportunities, time, money, and more. Considering the complexity of this construct, we describe a set of strategies used in VHOS to document changes in participants and the role that motivation plays.

Cogenerative Dialogues. Cogenerative dialogue (Tobin & Roth, 2006) is the approach used to engage youth in collaborating and constructing their VHOS environment. Such dialogues are youth-focused meetings which give them voice and choice and afford equal participation of youth and knowledgeable adults. However, these dialogues are not only activities that engage youth in making key decisions about their activities, they also serve as a way to collect data on youth’s perspectives about motivation and meaningful activity. Each participant in the cogenerative dialogue has voice and this supportive and open environment for discussion ideally minimizes power imbalances. By using a method in which participants work collaboratively with those in positions of power and expertise, youth are able to describe the difficulties arising within the project and co-create solutions. These dialogues also provide insights into the ways youth conceptualize STEM, STEM careers and the constraints and opportunities to pursue and sustain interest in STEM activities such as building exhibits in VHOS. These insights can greatly influence the education communities’ ability to create more meaningful, authentic activities, which will motivate youth to pursue and persist in STEM activities, education and careers.

Blogs. Building social networking spaces within this project to gather notes, make decisions, identify conflicts and accomplish work across time has been another effective, although unintentional way, to document which youth serve as motivators for others and who are not as engaged within the project as others. The blogs are part of the activity and were not originally meant to be a data collection strategy for research. However, the richness of some of the posts indicates that these online conversations are potentially useful data sources for documenting motivation. Entries that have more detail and create an atmosphere of teamwork and community have been good indicators of the levels of motivation of the students. The following post from one student demonstrates how he has taken the initiative to make roads within the virtual space to create order,

> Hello all!, just here to say that I have created our towns infrastructure if you were wondering. I took one night to do it and I made it so that the roads pass through in front of almost everyone's house. It also turns into a bridge at one point passing over a few of the houses :). when you get a chance, you may want to take a ride along the road...no telling in where it might take you...there is always more to explore my friends...(posted 3/16/2010)

This student was motivated to make roads because he needed to create organized ways of working in the virtual world. He knew that this space was going to be used and eventually would be visited by the public and took it upon himself to make roads. Utilizing these entries, we are able to determine which youth are motivated to participate and who are not. For those that seemed uninterested, we are able to take a step back and address the situation by adjusting different elements of the project. While this is a time consuming mechanism for documenting motivation, it is one that becomes part of the activity itself. Thus the blogs serve as a window for educators who design these activities to understand which elements of a program motivate students to persist and work through challenging moments.

Findings/Impact

The notions of identity and activity are dialectically related. As a person engages in social activity, her identity continues to form and transform mediated by the resources and tools she uses, by how she chooses to use them and by how others view her. As her identity continues to transform, the activity continues to be transformed. A person who sees herself as one who is an expert in science will approach the activity of facilitating science experiences differently than the person who does not. Therefore motivation is linked to participation in activity and consequently to identity formation. As one engages in meaningful activity and grows in the identification of self as an expert in that activity, it impacts the level of motivation. Youth in this project identify with being an Explainer, a person with some level of comfort and expertise in facilitating science conversations. When faced with the opportunity to apply this identity to a new setting, they are not only excited, but somewhat equipped to begin the activity. With scaffolding from the project leadership team, they develop their skills and gain new tools and resources to apply towards the activity. In the following statement, an Explainer describes how she and her teammates work towards designing age-appropriate exhibits:

> So today, they let us work on expanding our exhibit idea on the VHOS 3rd Floor. I thought about the feedback I have been getting about the concern of the age group for the VHOS Preschool Place, so I decided to just create it as the VHOS Kids Place. And I also made a sign saying that the recommended age is 6 and UP. Today I only built the outside of this place but when I get home I will expand it even more! I'm excited, and I really hope this idea can be successful.

What we witness from this excerpt is knowledge gained from working at the New York Hall of Science is being used to design a virtual space. Explainers are engaged in the collaborative practices of the museum. Through their ongoing learning and participation in museum activities, they become more intimately familiar with the behind-the-scenes workings of the institution. They value that some exhibits are more suitable for younger children and belong in a separate space and are able to engage in the design of such a space with some degree of professional knowledge. In the statement above, the students enact this collaborative knowledge to help one of their peers to make her space more age-appropriate. Experiences like these mediate the developing identity as a designer of STEM exhibits. These developing identities in turn mediate motivation for continued participation in the activity. The following statement from a different student supports this claim. This blog post is from his initial participation in the program. One of the first skill-building activities that Explainers engage in is learning to build their own house in virtual world. In the process of building their house, they gain experience with different tools like Google Sketchup and learn foundational computer programming skills that they will then apply to building a virtual STEM exhibit.

> Today I was on [in-world] from 4-10pm, working on my house and after 6 hours I am almost done. These six hours went by pretty fast and I am adding some finishing touches to my house. The new house I built is 3 stories high on almost the edge of homeland. Today I was basically addicted and really could not get myself off.

Laptops were made available for students to borrow and use at home to continue their activities. This particular student expressed that he was "addicted" to the activity. From our perspective, in his "addiction" he was using digital tools and gaining ICT skills that are relevant to participation in the STEM/ICT workforce. As researchers and practitioners we are, in fact, aiming to addict kids to these types of math and science activities.

VHOS is in the beginning of its third year and is about to engage its final cohort of high school students. The actual virtual world is populated with numerous STEM interactives and the project team is planning how this 3-D space will move from being a workspace to becoming a public site for virtual visitors. The Explainers will lead the development of the facilitation plan in partnership with full-time NYSCI staff and the evaluation being conducted by Center for Children and Technology is centered on measuring growth in Explainers' ICT skills and awareness of STEM careers. Although the evaluation is not specifically measuring how the project is impacting motivation, the project team can clearly note that the Explainers are enthusiastic about figuring out ways to bring their expertise in facilitation to a virtual environment. This project has allowed them to extend their Explainer identity to a new context and learn new roles in facilitating science-learning experiences for the public. The motivation is generated from within the Explainer group itself as they bring their prior experiences facilitating science with visitors to the physical NYSCI and share what has worked and what hasn't worked. Furthermore, they feel a sense of responsibility towards each other and to the project, which contributes to a collective motivation to excel. The following blog statement from one the students who has emerged as a leader from within the group demonstrates how students motivate each other:

> This is too [sic] all of my peers and colleagues. It has been brought to the attention of all of those who attended the in-world session at 6pm on today's date: 4/28/10 that we have been quite lax with our work. Lax in the sense that we are slacking. This is not what was expected of us, it isn't the duty of the leaders to keep you on track but you should want to keep yourself on track! SELF-LEAD! Please, I know we are capable of great things so lets get to it! FULL MOTIVATIONNN!; Oh and PLEASE look at the floor plans for VHOS, these are the plans we are going to build by so please adhere to them and try to construct your exhibits in the designated areas. Organization is key people, lets keep it up! Thank you, this is all I really have to say, OH! and please complete the surveys for the end of each week, these surveys should be completed before every Saturday, being that Saturday is the mark for the beginning of a new week. -Thank You,

We felt it was important to provide the entire blog entry in this paper because it provides evidence for this collective motivation. The student has pride in his group, knows his group's potential for success and does not want the project leaders to think otherwise. He encourages the other students to "self-lead"—an invitation to become proactive. He also reminds the others to complete what may seem like a repetitive task, to fill out the weekly evaluation surveys. This student is aware of the importance of the evaluation to the project—to the collaborative practices of the museum—and wants to ensure that his group is performing well in all areas. It is in these groups where the collective sense of motivation is quite strong. The project leadership team's role has been to harness this motivation and so that it not only supports youth in growing their skill set, but also meets the objectives of building a public virtual space.

Discussion

The process of engaging students in meaningful, authentic activities in which they are positioned in a central leadership/decision-making role can be a source of motivation. In this case, students build a 3-D interactive STEM learning space that will extend their role as Explainers into a new (virtual) context. The project team designed this activity for students to gain ICT skills while developing an interest in science, however the very nature of the project motivates students because they are doing something that will be for the greater good of the Explainers, the science center and ultimately the general visiting public. This project also opens up many questions to consider including:

- Given that motivation is dynamic, situated, and domain-specific and can be inferred from actions, what are some ways that we could observe and describe actions that indicate motivation? How can we reproduce the conditions that lead to those actions that seem to specifically lead to motivation? While this question is pertinent to many, it is especially relevant for educators who are responsible for designing experiences for youth and for policymakers who influence decisions about which programs and projects get funded.

- Issues of workforce development are compelling the nation to examine our practices, our policies and our assumptions about STEM teaching and learning. In this political climate, what can we learn about student participation and motivation in projects like these that would support career-focused STEM education? The project featured in this paper is designed to investigate awareness of and interest in STEM careers, however we became aware that the context of the project spurred students to persist and surpass meeting the project goals. In other words, the collective goal of the group to build something of relevance to multiple stakeholders seemed to be a central motivating feature. In what ways could this motivation in this STEM context be linked to motivation to pursue STEM careers? Or perhaps we should ask, how could we make more explicit the connection of the STEM contents and skills learned in a project to STEM careers that contribute to the greater good? If this were a central design feature of such projects, would this motivate more students to pursue STEM careers? What kinds of STEM careers would these students be drawn to? How could we document this trajectory?
- We discuss some possible ways of weaving research into practice, but what are other ways that researchers and practitioners can work together to understand when and how an activity motivates youth? How can we involve the youth themselves becoming self-aware about their motivation? How could we document this in ways that strengthen the body of literature in this area and lead to practical application in program development and implementation?

These are some initial questions worth exploring as we work to advance the body of research and practical activities that aim to motivate youth to pursue STEM careers and interests. Hopefully such questions will help us to not only expand our definition of motivation and the factors that support it, but also to think about ways to purposively design activities and engage youth in ways that will contribute to their STEM-related motivation and persistence.

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