Personal Learning Journeys: Reflective Portfolios as “Objects-to-Learn-With” in an E-textiles High School Class

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Abstract
Much attention in constructionism has focused on the design of learning tools and support for students building artifacts. Far less attention has been placed on reflection and reflective artifacts that let students consider their own learning. In this paper we share an analysis of portfolios in which high school students reflected on the design of their electronic textile projects during an eight-week curricular unit in an *Exploring Computer Science* class, an introductory computing course for high school (secondary) students in the United States. We examine portfolios as sites of student self-authorship: places where students showed agency in positioning themselves in relation to how they made their e-textile projects and to computer science more generally. In the discussion we consider the implications of reflective portfolios as objects-to-learn-with for educational implementation and constructionist pedagogy.

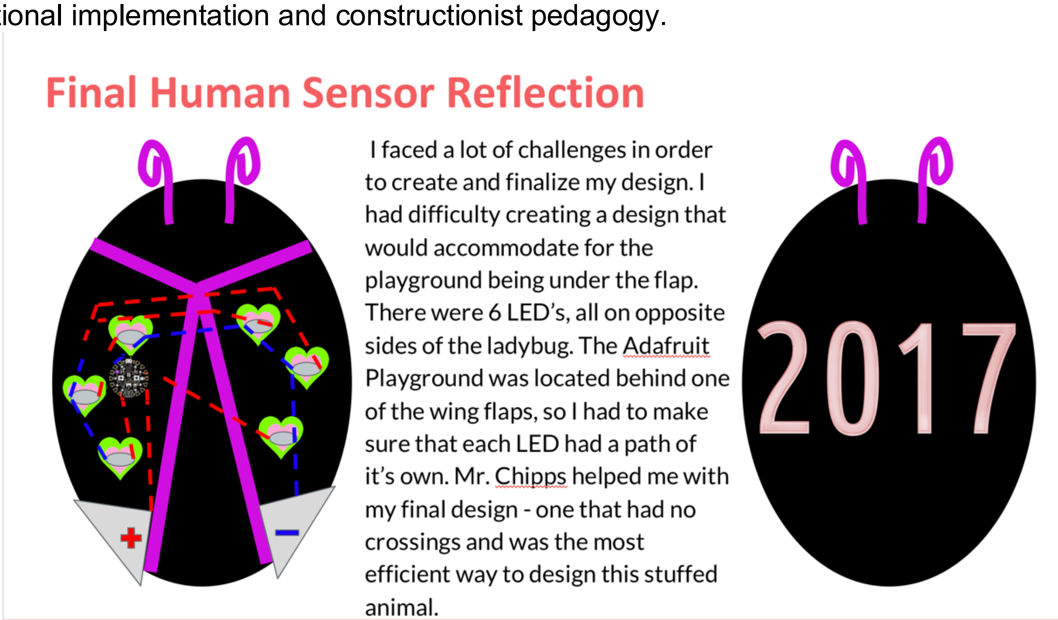

Figure 1. Ashley’s portfolio page on challenges in the human sensor project.

Keywords
Electronic textiles, computer science education, identity, portfolios, objects-to-think-with

Abstract

Much attention in constructionism has focused on the design of learning tools and support for students building artifacts. Far less attention has been placed on reflection and reflective artifacts that let students consider their own learning. the design of their electronic textile projects during an eight-week curricular unit in an *Exploring Computer Science* class, an introductory computing course for high school (secondary) students in the United States. We examine the portfolios as sites of student self-authorship: places where students showed agency in positioning themselves in relation to how they made their e-textile projects and to computer science more generally. In the discussion we consider the implications of reflective portfolios as objects-to-learn-with for educational implementation and constructionist pedagogy.

Introduction

> "Studying one's own learning process...can be a powerful method of enhancing learning."
> (Papert, 2001, p. 85)

Much attention in constructionism has focused on how how learners can construct knowledge through the design and interaction with artifacts ranging from Logo programs, video games, robots, and animations to 3D-printed and laser-cut objects (e.g., Blikstein, 2013; Harel, 1990; Kafai, 1995). To support young designers in constructing objects on and off the screen, hundreds of tools have been designed, including programming environments like Logo, Scratch, Squeak, Blockly, Snap!, and Alice in addition to construction kits such as Lego Mindstorms, LilyPad Arduino, MaKey MaKey, Chibitronics, and many more, working with materials such as Lego bricks, textiles and paper. A major emphasis has been on what kids can make and what they learn by making through "objects-to-think-with" that engage them with powerful ideas (Papert, 1980) and through "objects-to-share-with" that foster interactions with others (Kafai & Burke, 2014). An emphasis in this work is highlighting children's capabilities to make and create when they are provided with powerful tools such as computers. In these situations children and youth can make interest-driven, student-centered projects that are highly engaging and can promote rich learning through the process of creating these objects.

Far less attention has been placed on how learners can make their own learning an equally important focus as Papert (2001) suggested (see quote above) or formally reflect on their own learning with what we would like to call "objects-to-learn-with." Creating artifacts and reflecting on both the process of making them and the products themselves engages students not only with disciplinary learning, but just as importantly supports students' authorship of their own identities or senses of self within a particular discipline, i.e., a "disciplinary identity" (see Van Horne & Bell, 2017). Being able to author one's own disciplinary identity may be especially important in a field such as computer science, a field that is well-documented as historically exclusive and in which many students often struggle to develop a positive sense of self or sense of belonging (e.g., Cheryan, Plaut, Handon & Hudson, 2013; Yardi & Bruckman, 2007). To help students articulate a clear sense of self or self-narrative in relation to a discipline presents a critical dimension of the learning process (e.g., Carlone, 2017) and would suggest involving learners in documenting their own development in design notebooks or portfolios that could capture their reflections on their learning processes and outcomes. Such reflective artifacts could engage students in making their own learning an object-to-learn-with —just as much as the actual design of games, robots or software already does—and uncover how they see themselves establishing (or not) personal connections with academic disciplines.

In this paper we share the design and analysis of learner-generated reflective portfolios that accompanied the development of a series of electronic textile (hereafter e-textile) projects that high school students completed during an eight-week curricular unit in an introductory *Exploring*

Computer Science (ECS) class (Goode, Chapman & Margolis, 2012). E-textiles are hybrid designs, consciously combining traditionally "masculine" activities such as engineering and computing with traditionally "feminine" activities such as crafting and sewing (Buechley, Peppler, Eisenberg & Kafai, 2013). Portfolios have been extensively used as a means of assessment, for instance, in studying how students reflect on their academic learning by documenting computational thinking concepts and practices learned (see Chang et al., 2015; Lui, Jayathirtha, Fields, Shaw, & Kafai, 2018). However, here we wanted to focus on another equally important aspect of constructionist learning—that of personal expression and connection to the academic discipline—which could uncover critical aspects of students' identities as learners in the field of computer science. This led us to consider the portfolios as sites of student self-authorship, places where students could show agency in positioning themselves in relation to how they made their e-textile projects and to computer science more generally. In this paper we ask, how do students use reflective portfolios to express their own voices and self-authorship in relation to computer science? In the discussion we consider the implications of reflective portfolios as objects-to-learn-with in constructionist learning environments where students can personally express themselves as well as the ramifications for educational implementations and constructionist pedagogy more generally.

Background

Early constructionist activities such as the instructional software design (Harel, 1990) or game design projects (Kafai, 1995) included reflection in the form of design notebooks. For instance, when children designed Logo software and games, they also wrote out daily reflections on the "problems and changes they made each day" (Harel & Papert, 1991, p. 6). These journals or design notebooks encouraged students to reflect on what they were learning and supported self-awareness of the process of creating as students noted how their projects changed as they moved through the process of making them. While notebook entries captured changes in students' thinking and designs, such reflections tend to be under-analyzed in comparison with the actual programmed artifacts (e.g., games, software) that were created by learners (e.g., Reynolds & Caperton, 2011). A further limitation is that even the learners considered the notebooks transitional or process artifacts, as they ultimately did not become part of students' final artifacts that were shared with a wider audience.

In contrast, portfolios have begun to emerge as potential culminating artifacts in some classrooms to showcase students' work, accompanying the actual project(s) that students have made. For instance, portfolios featuring the best projects or series of projects students have made, as in a professional art portfolio, highlight students' accumulated competency and skill (Býrgýn & Baký, 2007). Portfolios can also be process-based, showing students' progress through a series of projects or even within a project (e.g., Chang, et al., 2015). Here students can narrate how they have grown throughout the creation of a single project or across multiple projects, allowing students to author their own pathways of learning through reflection. While portfolios are more common in arts education, more recently they have appeared in computer science education. For example, in the Advanced Placement Computer Science Principles class, students submit both a project and a portfolio that explicates the intention behind their projects as well as documents how they were made (College Board, 2017). Thus the portfolio supplements the project itself and can be used as a type of learning assessment for academic content.

In addition to serving as a learning assessment or a demonstration of learning progress, the type of narration that portfolios encourage holds equal potential to be a key resource in supporting students' authorship of "disciplinary identity" (see Van Horne & Bell, 2017). Identity is a broad concept that, from a sociocultural perspective, includes how people act in particular situations (practice-based identities), how people think about themselves (self-narratives), and how other people perceive someone (others'-narratives) (see Fields, 2010). Though creating personalized artifacts linked to core disciplinary content can support students' identities in practice-based ways (Van Horne & Bell, 2017), the design process alone may not necessarily help students articulate a clear sense of self (i.e., self-narrative) in relation to a discipline. In this paper we are primarily concerned with the aspect of identity that relates to students' self-narrative—how they think about themselves (Fields, 2010). In discussing identity development, Nasir and Cooks (2009) argue for the importance of "ideational resources" in developing and establishing one's identity within a particular learning space. Ideational resources are the "ideas about oneself and one's relationship to and place in the practice and the world, as well as ideas about what is valued and what is good" (p. 44). Ideational resources might include specific lessons or sayings about how to manage one's emotions in a challenging scenario or how to name oneself in relation to others, for instance as a core participant in a community (i.e., a "hurdler" or a "jumper" in track-and-field or a "problem solver" in a computer science class). Having a sense of self as a type of computer scientist or as having characteristics of capable computer scientists can situate students on an inbound trajectory of participation in a discipline.

In turning to portfolios for capturing students' identities as learners, we suggest that they can become an ideational resource in helping students express who they are in relation to an academic discipline or field, namely computer science. By combining the process features of the early design notebooks of constructionist projects (Harel, 1990) with the product features of portfolios found more in arts education, we can turn reflective portfolios into meta-artifacts, or objects-to-think-with, in which students express what, why, and how they have made a computational artifact and thus begin to narrate, in their own personalized ways, who they are within the field of computer science. Below we describe the type of portfolio that students made in the e-textile curricular unit, a portfolio that was both project-based (featuring a series of artifacts students made) and process-based (highlighting challenges and revisions made in the process of making the projects). Then we explore the ways that students expressed and authored themselves through the personalized portfolios that they created, ending with a discussion about the implications for educational implementation and constructionist pedagogy.

Methods

Curriculum & Portfolio

Over the past two years we have co-developed an e-textiles unit for the *Exploring Computer Science* curriculum, a year-long course providing an introduction to computing with equity-focused and inquiry-based teaching (Goode, et al., 2012). The e-textiles unit took place over eight weeks and consisted of a series of four projects: 1) a paper-card using a simple circuit, 2) a wristband with three LEDs in parallel, 3) a classroom-wide mural project where pairs of students created portions that each incorporated two switches to computationally create four lighting patterns, and 4) a "human sensor" project that used two aluminum foil conductive patches that when squeezed generated a range of data to be used as conditions for lighting effects. Each project allowed increasing flexibility in design and personalization, and the human sensor projects reflected this in the diversity of students' projects: stuffed animals, paper cranes, wearable shirts or hoodies, handbags, and gifts for family members.

In the second year of implementation, with the help of two teachers, we revised the unit, adding reflective portfolios as a capstone to accompany the final project of the unit. The portfolio that students created was co-developed with Ben, the teacher of the ECS class that is the subject of this paper. The portfolio was both a project- and process-based portfolio, showing the series of projects students made as well as reflections about their processes of making them. The portfolio consisted of a set of at least four Google Slides for each project, with students adding on slides until the portfolio contained reflections on all four projects. For each project, the requirements included: 1) an initial drawing of the project and a reflection on changes made to the project, 2) at least one challenge they faced and an explanation of how they dealt with it (see Figures 1 and 3), 3) how they had “grown as a computer scientist” accompanied by at least one picture or video of their work in progress (see Figure 2), and 4) a picture/video of the final project with an explanation of what it did plus a reflection about what they learned and how the project fits into their identities as computer scientists. The portfolio ended with one final reflection on students’ learning across the entire unit. Figures 1, 2, and 3 provide examples of how students chose to illustrate the different parts of the portfolio assignment, as well as how students personalized their portfolios. All but one student personalized their portfolios by using specialized fonts and backgrounds, adding title pages for each project, creating digital representations of their projects, and incorporating selfies or images that exhibited their own styles and interests.

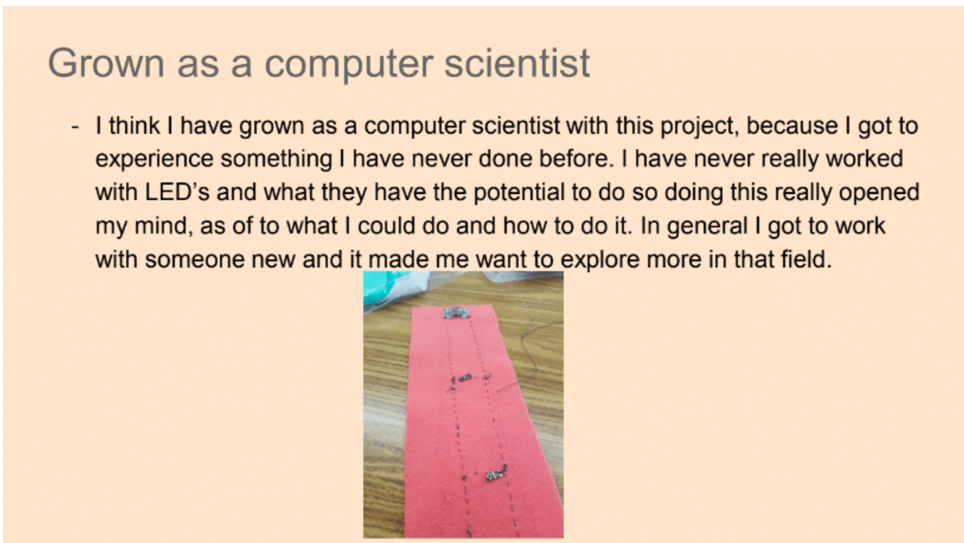

Figure 2. Alejandra’s portfolio page on growing as a computer scientist after the wristband project.

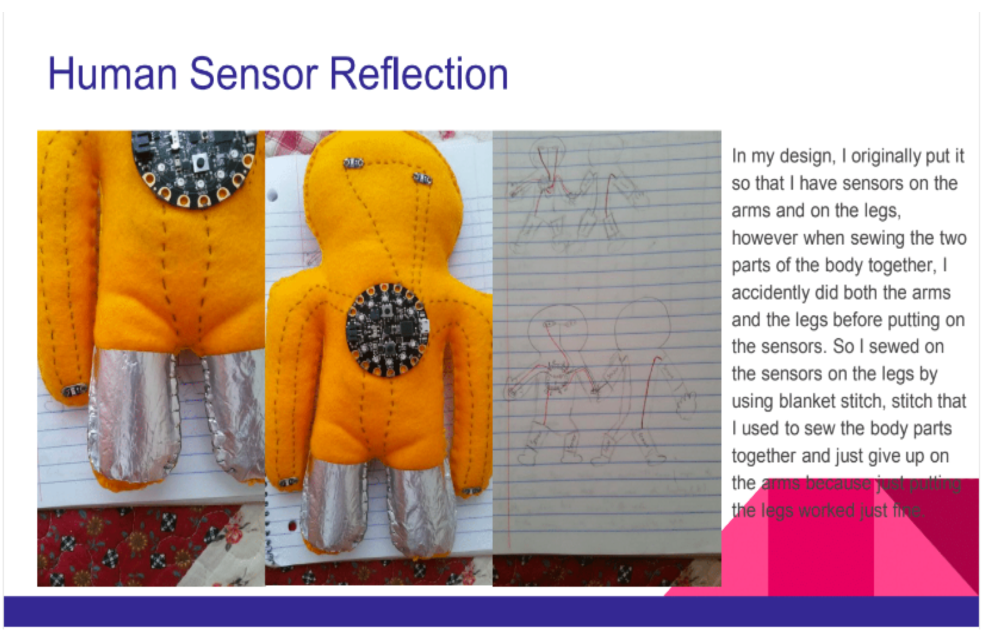

Figure 3. Louis’s portfolio page on challenges in the human sensor project.

Ben piloted the e-textiles unit in Spring 2017 in his ECS class with 35 students (13 girls and 22 boys), with 32 consenting to participate in the research project. Most students were in 9th grade (14-15 years old); one student was in 12th grade (17 years old). Ben's school was socioeconomically (54% of students being from socioeconomically disadvantaged families) and ethnically diverse (i.e., the student population consisted of 4% African American, 18% Asian, 10% Filipino, 40% Hispanic or Latino, 25% White, 1% as two or more races, and 2% race not reported). The school had a three-year trajectory of elective (i.e., optional) computer science courses, with ECS being the introductory course.

Data and Analysis

The data for this project included the digital portfolios from all 32 consenting students in Ben's class, and we sought to develop a framework to analyze how students utilized the portfolio assignment to author themselves in relation to computer science. Through multiple rounds of grounded, comparative analysis (see Charmaz, 2002), we initially developed 11 codes grounded in the identity statements students generated as answers to the question "How have I grown as a computer scientist?" However, we found these codes limiting, as we noticed that students authored themselves in relation to computer science in more subtle ways outside of the slides dedicated to identity statements. After a second review of the portfolios, we expanded our analysis to the entire portfolio and through a further two-step iterative process, consolidated all original codes into six broad categories:

Self as a Computer Science (CS) Person

- **Computational:** Students author themselves as problem-solvers and relate this to doing computer science or being a type of computer scientist.
- **Personal:** Students explicitly link growth as a computer scientist with specific skills they learned, such as coding or making circuits.

Self and CS as Personal

- **Socioemotional:** Students describe how doing the project or the project itself demonstrates personal characteristics like dedication, perseverance, patience, getting out of one's comfort zone, making mistakes, or collaborating with others.
- **Relational:** Students express a relationship with a friend, family member, or teacher that either provided feedback on the e-textile project, involved collaboration, or made a project intended for someone else.

Self in Relation to the Larger Field of CS

- **Aspirational:** Students discuss themselves in a future tense in relation to computer science in the context of applications outside the classroom such as future jobs or in other projects.
- **Projectional:** Students describe new realizations of what computer science is or what it can include.

Two researchers then applied these codes systematically to the 32 portfolios to better understand students' direct expressions of identity with computer science and being a computer scientist through completing the e-textiles unit. Together these two stages of analysis helped unveil how the portfolios afforded students the space to articulate how they identify with computer science.

Findings

Throughout our analysis of Ben's students' portfolios, we discovered that in addition to serving as a tool to assess student learning of computer science content (see Lui et al., 2018), the portfolios afforded students the space to author themselves in relation to computer science. In constructing their portfolios, students not only articulated who they were in relation to computer science but identified the various resources, skills, and personal qualities that helped them construct their artifacts. In addition, the portfolios allowed students to author new and expanded understandings of computer science as a field. They also allowed students to narrate who they could be in the future in relation to computer science, articulating what lessons they learned that could help them succeed in computer science beyond this unit.

Identifying as Types of Computer Scientists

Answering the question “How have I grown as a computer scientist?” in their portfolios afforded students the opportunity to author themselves explicitly as computer scientists. Many students did so by articulating *specific functional skills* they exhibited throughout the unit that they believed aligned with being a computer scientist. In total, 20 students said that they had grown as a computer scientist through developing specific skills: 14 of these students listed specific coding skills, 12 cited circuitry skills, and 7 mentioned crafting skills (some students cited multiple skills across their portfolios). For instance, Leon claimed, “This project has helped me become a better computer scientist by being able to code light functions, and making them.” Other students linked being a computer scientist with things such as making LEDs light up, learning how to program a microcontroller, and even how “to create a fabric with LED’s in it” (Jeevan). The frequency of students linking being a computer scientist with particular skills is striking and shows the association they saw between being a computer scientist and the things that they learned in class while creating projects—they saw a direct link between what they were doing and who they were as computer scientists.

This direct link between doing and being is also visible in the ways that students associated being a computer scientist with problem solving. In all, 17 out of 32 students authored themselves as *problem solvers* specifically in relation to computer science. Jarvis expressed this the most obviously in writing, “This has definitely helped me as a computer scientist as a lot of computer science is problem solving.” In this, Jarvis made a direct statement that computer science is problem solving, and since he did some problem solving in his work, he therefore was “helped” as a computer scientist in the making. Other students explained this connection between being a computer scientist and problem solving as “realizing my mistakes so I do not make the same mistakes the next time” (Jeevan), or saying that the project experience “allowed me to solve my problems on my own and work till I figured out a solution” (Anita), or that “My final project shows that my identity of being a computer scientist is I get what to do but I mess up a lot” (Ana). This connection between problem solving and identity is intriguing because problem solving is a more general skill or way of thinking than particular forms of coding, crafting, or making circuits discussed above. Students’ highlighting how to problem solve or work through challenges reflects broader, intentional teaching practices in the classroom community valuing mistakes and failure as legitimate means of learning (see Fields, Kafai, Nakajima, Goode & Margolis, in press). It also reflects the values behind the requirements of the design notebook and the portfolio, showing that students respected challenges and the processes of working through them.

In positioning themselves as having new skills in computer science as well as abilities in problem solving, these high school students challenged the common notion of not being “smart enough” to participate in computer science (Yardi & Bruckman, 2007). In other words, as opposed to being told what computer scientists do or what kinds of people they are (which can act as a barrier for participation in computer science), the students personally authored what they did throughout the e-textiles unit and how that confirmed their identities as computer scientists.

Relating to Computer Science as Personal and Social

Intriguingly, beyond listing particular skills and practices, 12 students also linked demonstrating socioemotional characteristics to being computer scientists. Consider Ashley’s explanation about being creative and taking risks, “This project fits into my identity of a computer scientist because it allows me to go out of my comfort zone and create something new. Creating doesn’t only mean put everything together, but it also means to imagine, discuss, evaluate, and understand." Here Ashley explored an expanding view of creativity with her willingness to step out of her comfort zone as important personal attributes she associated with being a computer scientist. Other students expressed how they felt "more capable" (Heidi), how their project work improved their "patience" (Anita) or how the process of making e-textiles demonstrated "hard work" that developed through "constant practice" (Adeep). For these students, computer science was more than just learning specific skills or coding; they linked CS to involving personal attributes that they valued.

In addition, students particularly challenged the stereotypical perception of computer science being antisocial (Yardi & Bruckman, 2007). In total, 18 students acknowledged *relationships* as serving a role in the construction of their artifacts, whether it was by working with a partner on the mural project, gaining help from their peers or the teacher, or eliciting feedback from peers or family members. Heidi, for example, came up with her project idea by eliciting feedback from both her mother and her peers as she shared, "Unfortunately my mom didn't want me to sew one of my pants, so it was between a corgi pattern or the flowers. Many people wanted the flowers so eventually I decided to do flowers on the bag." In other words, Heidi valued people's opinions in her design process, truly conceptualizing her e-textile project as an "object-to-share-with" (Kafai & Burke, 2014). Four other students specifically designed their e-textiles artifacts as gifts for family members, integrating relationships in the purpose of their designs. For example, both Jeremy and Ana designed their electronic cards for their mothers, while Ashley and Sara designed their human sensor projects (a ladybug and a wolf, respectively) for their little sisters. Designing their projects for family members and leveraging those relationships created additional meaning and relevance for students in considering the role computer science plays in their lives.

What is interesting about students noting how relationships played a role in their projects rests on the fact that most of their projects (aside from the mural project) and their portfolios were individual assignments. However, in reflecting on their learning through their portfolios, over half of the students recognized how others played a role in their being able to construct their projects, demonstrating how without explicit prompting they were able to author an expanded understanding of computing as a social field. By acknowledging the social aspects of computer science, students who normally view the field as antisocial can develop an increased interest and sense of belonging, such as Alejandra who stated, "In general I got to work with someone new and it made me want to explore more in that field."

Situating Selves with Computer Science as a Field

The portfolios also afforded students the space to author new and expanded understandings of computer science as a field. In analyzing all of the portfolios, we found that 14 students described new realizations of what computer science is outside the classroom. For example, Kevin learned that "there is coding in everything," when he came to realize that lights required a software program to turn them on and off. Other students shared discovering new ways that computer science is done. For instance, as opposed to computer science being a highly regimented field with limited ways to participate, Adeep reflected how "this project [...] helped me grow as a computer scientist by showing me that computer science does not have some sort of a handbook." It should be noted that students were not required to reflect on computer science as a field. However, in reflecting on their identities as computer scientists, students positioned themselves in the field by broadening its criteria in ways that validated their participation. In addition, they reflected on how what they did in completing their projects related to how computer science is done in the real world, which speaks to how they were able to create meaning and relevance from their projects.

Other students, 12 in all, authored themselves as participating in e-textiles projects in the future, including Shona who expressed interest in doing "both of these projects again due to the wonderful experiences I have gathered." In addition to wanting to make e-textiles in the future, students like Leon and Ashley identified specific lessons they learned from the projects that they would apply for future e-textiles projects, such as listening more carefully in order to make fewer mistakes (Leon) or creating an initial plan before designing (Ashley). By identifying these lessons, there were given the opportunity to reflect on how they could improve upon their initial designs and experiences, increasing their chances of success. Other students like Jesse expressed interest in exploring computer science past the e-textiles class, particularly in college. Interestingly enough, one student, Mario, explicitly stated that he did not want to be a computer scientist in the future: "It might help me get a job or be memory i won't forget that turns into a skill. Or I can help my family with problems that deal with computers." Even though Mario had expressed in his portfolio that he did not want to be a computer scientist, he still named meaningful ways he could apply what he learned in the e-textiles unit to his future.

It is fascinating how students used the space of their portfolios to author these future selves in relation to computer science. This reflects how portfolios can serve as ideational resources that allow students to construct identities of themselves participating in computer science in the future in ways that are personally relevant. Doing so affords students the opportunity to develop positive self-narratives that situate them on an inbound trajectory of participation in computer science.

Discussion

When Papert (2001) wrote about valuing the study of one own's learning, he was reviewing his own journey—the various experiences, activities, and observations of learning—that contributed to his conceptualising learning as a multi-facetted process of connecting with the world. Students engaged in very much the same approach in reviewing their learning as they created their portfolios in addition to and in review of their e-textile artifacts; both served as powerful ways to reflect on their own learning process and identities as e-textile designers. Not only did students apply computer science in real-world contexts through constructing their e-textiles artifacts but constructing their portfolios provided them with the opportunity to author new understandings of computer science in ways that were meaningful to them as well as increased their interest in the field. In other words, as opposed to holding negative perceptions of computer science, students were able to reframe their perceptions of computer science as a more relevant, sociable, and engaging field.

From "Objects-to-Think-With" to "Objects-to-Learn-With"

We started out with the observation that constructionist theory and practice have emphasized the construction of artifacts as "objects-to-think-with", on and off the screen, as a primary vehicle for learners' knowledge reformulation and personal expression. Adding to this is the importance in constructionism of creating objects in a supportive social environment. In creating shareable artifacts, learners' knowledge construction becomes not only an individual but also as a social process. One could argue that by designing for an audience, learners have an opportunity to share the understanding they have gained from making something and in the process revisit their learning. We have called this dimension "objects-to-share-with" (Kafai & Burke, 2014). For instance, in Harel's (1990) instructional software design project learners developed software to teach others. However in this instance the point of reflection was always another person—customizing software for the user—not the designer. The reflective portfolios studied in this paper move the examination of learning back to the learner him or herself. While objects-to-think-with have student-created artifacts as the focal point, reflective portfolios become "objects-to-learn-with," places where students can trace their path of learning, record what they have discovered, and situate themselves as learners within a larger disciplinary community.

Identifying with Process and Mistakes

The portfolios also served as ideational resources (Nasir & Cooks, 2009) that supported students' authorship of who they were (i.e., students' expressions of identity) in relation to computer science. Most students in Ben's class clearly articulated themselves in relation to computer science, whether expressing that by describing the skills they learned, the types of problem-solving and persevering people they had become, or the friends, family and teachers who were part of their learning experiences. It is further evident from students' reflections that many felt able to clarify the *type* of computer scientist they were: as someone who "messes up", fixes things, thinks out of the box, works collaboratively with others, or "solves problems on my own." Here students were not limited to culturally dominant stereotypes about the types of people who do computer science (Yardi & Bruckman, 2007). Instead they linked their personal interests and experiences in authoring *new* ways of participating in the field of computer science.

There are interesting parallels and links between the reflective portfolios students wrote and the e-textiles artifacts they made. Both are interest-driven and student-centered; students molded projects in relation to their own personal interests and shaped their portfolios in similar ways. Both had constraints that helped shape what students made. In the e-textiles projects, students were constrained by using certain tools or creating a number of lighting patterns; in the portfolios students had to fill in specific sections with writing and evidence. Both allowed for personal aesthetics. E-textiles projects varied based on students' interests and showed visible links to family, schools, or popular culture; e-textiles portfolios differed in fonts, backgrounds, digital images, and discourses of writing. In this we argue that portfolios like the ones students created in Ben's class are a type of secondary artifact, one that can accompany the type of personalized object usually focused on in constructionist-based learning environments. Yet while the primary artifact (i.e., an e-textiles or another project) only shows the end product, portfolios complement this by sharing the stories behind the e-textiles artifacts' creation: troubles encountered, mistakes made, revisions that took place, and people who influenced the design. While the primary artifact hints at students' identities in the skills exhibited or interests made visible, portfolios allow students to explain in explicit ways what type of people they are and how they relate to the broader field in which they are participating.

Constructing Spaces for Learning Journeys

Just as we design tools and communities for supporting students' constructions we need to attend to the design of tools for reflection. Some key affordances of the portfolios in this study could be applied to portfolios or similarly reflective artifacts in other contexts. One requirement of the portfolio in this study was to write about challenges faced and changes made in the projects. This constraint may have had a direct influence on students' prioritizing qualities such as problem solving, troubleshooting, persevering, and having patience. Another helpful requirement was specifically designed by the teacher: explaining "how you have grown as a computer scientist." Ben created this requirement to explicitly support students' identity development, and his success is evident in the frequency with which students associated certain skills or personal qualities with being a computer scientist or doing computer science. In future research we are investigating variations of these design features as well as other formats and contexts to understand how to facilitate students' reflections.

For instance, in our case, the portfolios were created in Google Slides format, very much resembling PowerPoint presentations. Yet there is an implicit contradiction in using a presentation format that is often introduced as visual medium with as few words as possible for a reflection journal that asked students to elaborate in writing about their creative process. While the visual component is invited in presentation format, the textual component is not. In the next iteration of the portfolio assignment which is being applied in more than a dozen schools, teachers are choosing different formats for their classes, including blogs, websites, documents, and, of course, slides (though those could be oriented as a landscape or portrait format in ways that make them more or less like a traditional document). We plan to analyze to what degree different formats support students' creativity and self-expression in their reflections. Further, we are maintaining and adding to some core constraints for the portfolios, while allowing teachers to have the flexibility to add to them. For instance, the new portfolio assignment has doubled the emphasis on challenges and revisions (each student must share at least two instances of facing a challenge or revision) but has no requirement to express how students have grown as computer scientists. We will study to what degree students continue to author themselves explicitly in relation to computer science with and without that obvious prompt.

In this study, we focused attention on understanding how not only the construction of a personal and shareable artifact itself but the accompanying construction of a reflective portfolio could support students' learning journeys. Portfolios as meta-artifacts or objects-to-think-with deserve their own place in thinking about the philosophy and pedagogy of constructionism and how the combined artifacts can contribute to students' growing self-narratives in a broader disciplinary area.

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