Some Reflections on Designing Constructionist Activities for Classrooms

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Abstract

In this paper, we present our guiding principles for designing a constructionist curricular unit called *Stitching the Loop* with electronic textiles which introduce high school students to key concepts in crafting, circuit design and computing. Our principles were to design for (1) engagement by promoting interest-driven designs; (2) expression by putting aesthetics first; (3) depth by developing challenging content within constraints; (4) multiple experiences for providing opportunities for practice; (5) audience by sharing designs; (6) collaboration by having students help other students; (7) reflection by including design notebooks and portfolios; (8) failure by having students and teachers model and celebrate mistakes; (9) practicalities that transform classrooms into maker studios; and (10) iterations, iterations, iterations. Over three years, we worked together with dozens of high school teachers and hundreds of students in implementing and revising classroom activities in which students design and craft a series of individual and collaborative electronic textiles projects. Situated within the larger framework of the year-long *Exploring Computer Science* curriculum, we illustrate how these guiding principles fostered an equity- and inquiry-oriented pedagogy through which teachers could contribute to and support students' learning.

Figure 1. Gallery of sample student projects in the e-textiles unit: Paper Circuit, Stitchcard, Wristband, LilyTiny (upper row); Mural Project Selections, Human Sensor Project (lower row)

Keywords curriculum; coding; computer science education; electronic textiles, constructionism, maker movement

Abstract

In this paper, we present our guiding principles for designing a constructionist curricular unit with electronic textiles called Stitching the Loop, which introduces high school students to key concepts in in crafting, circuit design and computing. Our principles were to design for (1) engagement, (2) expression, (3) depth, (4) experiences, (5) audience, (6) collaboration, (7) reflection, (8) failure, (9) practicalities, and (10) iteration. Over three years, we worked together with dozens of high school teachers and hundreds of students in designing, implementing and revising classroom activities where students design and craft a series of individual and collaborative electronic textiles. Situated within the larger framework of the Exploring Computer Science curriculum, we illustrate how these guiding principles fostered an equity- and inquiry-oriented pedagogy through which teachers could contribute to and support students' learning.

Introduction

In constructionist approaches to learning and teaching, much emphasis has been placed on the design and development of construction kits (Resnick & Silverman, 2005). Hundreds, if not thousands, of digital, physical and hybrid construction kits have been developed to help students engage with STEM topics and express their ideas and personal interests (e.g., Blikstein, 2012). Far less attention has been given to the design and development of curricula where constructionism connects to academic content within a classroom. While curriculum design is often seen as contradictory to constructionist pedagogy because it constrains and directs student activities, we argue that it can broaden access to both making and coding, deepen learning in those fields, and promote better diversity in what is being made. This is particularly important in coding and maker activities which have a longstanding history of inaccessibility to non-White, non-male students from working-class communities (Margolis, Estrella, Goode, Holme, & Nao, 2017).

In this paper, we report on the design of an eight-week long formal curricular unit, called "Stitching the Loop," which facilitated students' interest-driven projects, supported peer collaboration, and applied equity-minded teaching. Our electronic textiles (e-textiles) unit was situated within *Exploring Computer Science* (ECS), an equity-focused and inquiry-based year-long introductory computer science course taught in public high school classrooms all over the country (Goode, Chapman & Margolis, 2012). We concentrated on bringing creative making in the form of e-textiles into computer science classrooms. E-textiles are hybrid designs, using conductive thread to sew LEDs, sewable microcontrollers (e.g., LilyPad Arduino, Adafruit Circuit Playground), sensors and other actuators into fabric or similarly soft media (Buechley & Eisenberg, 2008). The unit consists of a series of four open-ended projects with creative constraints that help students learn challenging concepts in computing, electronics, and crafting three-dimensional designs while also supporting personal expression and creativity. In the following sections we review different approaches to constructionist curriculum design and articulate the guiding principles we developed in designing the e-textile activities for "Stitching the Loop."

Background

Arguably the first constructionist curriculum was published in 1971 as a memo titled "Twenty Things To Do With A Computer" in which Papert and Solomon suggested a variety of activities that could engage children in programming, among them: making a turtle draw images on paper by programming a pen to lift up and down; programming behaviors such as the turtle following along walls in a room; engaging in geometry by writing programs to draw spirals, making an online movie by programming a change in petals on a flower, programming sounds to play a song, playing spacewar games, and many more. The memo concludes its list with the last recommendation asking the reader to come up with twenty more things to do with a computer.

This curriculum consisted of a *collection* of different projects, not necessarily organized in a sequence. Projects promoted what Papert (1980) called "powerful ideas" about computing such as recursion or repetition by situating them in visible realizations such as drawing flowers or circles. They also connected to other academic subjects providing an alternative way for children to experience geometry or mathematics. Furthermore, they sought out compelling applications such as making music or movies or playing and designing games that would resonate with students' interest. These features have become guiding principles for many other constructionist efforts, for instance, the development of the recent guide to *Creative Computing* (Brennan, Balch, & Chung, 2014) for Scratch activities.

A different approach to constructionist curriculum has been software design for learning, where *one project* becomes the central focus, such as designing instructional software (Harel & Papert,1990). Here students work on designing software such as learning tools or educational games that teach academic content like mathematics or science. In this context, the learning of programming is connected with the learning of academic content by teaching subject areas to others through designed software. For instance, software games designed by students (Kafai, 1995) included multiple problems in words, graphics, and often provide stories and animations. Furthermore, students created a whole product by including software package design and advertisements. A key distinction to the previous efforts is that in designing software applications, students work on a complex, long term project rather than a collection of several smaller ones. Another dimension is that students journal about their ongoing design process in notebooks outlining project ideas and reflecting on their challenges.

More recent approaches have combined elements from these two approaches by providing an explicit sequence of projects, such as game design as in Repenning and colleagues' (2015) "Scalable Game Design," which engaged students in a series of game design projects with Agentsheets. Likewise, Globaloria (Caperton & Reynolds, 2011) includes a year-long game design curriculum with a supporting social network where students can post and comment on games. Building on studio design pedagogy (Hetland, Winner, Veeenema, & Sheridan, 2013), Fields and colleagues (2016) created a weeklong Scratch Camp where students engaged in an intentional series of projects with creative constraints interjected with mini-lessons, gallery walks, and a final interactive event sharing with families and friends. Our curricular e-textile unit combines the collection of projects and the one-project approaches by creating an intentional series of projects with creative constraints, culminating in a final project with a reflective portfolio. Below we share the guiding principles for the e-textile curricular unit.

Guiding Principles for *Stitching the Loop*

The *Stitching the Loop* curriculum contains big ideas, recommended lesson plans, and sample rubrics, with much room for students and teachers to interpret and bring in their own style, evidenced in the different but successful ways it has been implemented over the past three years. It is accompanied by a 60+ page technical guide with fine-grained tutorials about crafting, circuit design, coding, and troubleshooting. By consciously combining traditionally masculine activities such as engineering and computing with traditionally feminine activities such as crafting and sewing, e-textiles can disrupt preconceptions about who can do computing, engineering, and crafting (Kafai, Fields & Searle, 2014). With this background, we brought together experts in e-textiles educational activities and the ECS development and implementation team. The curriculum was co-developed to combine best practices of teaching and creating e-textiles based on a constructionist philosophy alongside ECS principles (inquiry, equity, and computing) and style.

Over the past three years, we have written and piloted the curriculum with two teachers (Year 1—Spring 2016), four teachers (Year 2—Spring 2017), and now 17 teachers (Year 3—Spring 2018) in one of the largest and most diverse school districts in the United States. All teachers participated in 3-4 days of professional development, focusing on creating the core projects (see Table 1) and reflecting on principles of the unit like valuing aesthetics, personalization, mistakes, and audience. Between implementations we used analysis of observations and interviews with teachers and students to revise the unit. Our experiences in creating, revising, and implementing this unit highlight the possibilities in introducing making to computer science in ways that promote equity, imagination, and personalization in classrooms.

Table 1. Overview of projects in Stitching the Loop curricular unit

Project	Content	Description
#1 Paper Circuit (~1-2 hrs)	Single circuit project design: Create a simple paper circuit greeting card that includes one LED. Introduce the concept of aesthetic design and personalization.	· Simple circuit · Polarity · Materials: LEDs, copper tape (wire), paper
#2 Wristband (~5-6 hrs)	Simple wearable project: Create a wristband with three LEDs in parallel and a switch that turns on the project when the ends of the wristband are snapped together.	· Parallel circuit, switch · Reading circuit diagrams · Three-dimensional project · Deconstruction · Materials: Conductive thread, LEDs, fabric
#3 Collaborative Mural Project (~10 hrs)	Collaborative project: As a class create a mural, with each panel made by two students. Each panel must have five independently programmable LEDs and two switches, allowing for four blinking light patterns.	· Programming: Sequences, conditionals, embedded conditionals *or* Boolean statements · Collaborative work & division of labor · Materials: Conductive thread, LEDs, fabric
#4 Human Sensor Project (~10-14 hrs)	Capstone project: Create a project with two aluminum foil patches that act as a sensor when both are touched by a person. Program four+ lighting patterns based on different sensor readings.	· Sensor design (handcrafted) · Programming: operators, sensor range, Boolean statements · Materials: Conductive aluminum foil, human body, LEDs, fabric

We made several changes as we developed the unit. One of the most important involved a change in assessment as we shifted from pre/post-tests to reflective portfolios where students summarized their final projects, shared challenges that came up, and wrote about their progression during the e-textiles unit (Lui et al, 2018). The portfolio served to support student meta-reflection on their learning and to emphasize the *process* of making as much as the final *product* of making. The leadership model of the PD also changed as the two teachers from the first year of implementation took over nearly all training activities in the third year, bringing their hands-on expertise about managing students' creative making, teaching students how to sew, organizing materials, and handling classroom management in the e-textiles unit.

Designing for Engagement

We designed the e-textiles unit for engagement by keeping all projects open-ended, allowing students to express their interests, hobbies, and personal relationships in the artifacts. This was demonstrated by the vast diversity of students' projects and in students' own consistent expressions of creative freedom in the projects. As one student related, "I was able to make something that I wanted, anything, and I just created that and I liked it. It was fun." In some instances, students also displayed their engagement and relationships by designing their projects for others such as making a touch-sensitive soft toy for a little sister or making a blanket throw for a brother's birthday.

Designing for Expression

The unit emphasized "aesthetics first" through a personal design or sketch at the beginning of every project. In prior studies we found that starting with instruction (i.e., ways to design circuits) instead of design resulted in poor engagement by students (Kafai et al., 2014). In contrast, by having students sketch out what they want their projects to look like, even if those are technically or practically infeasible, encourages personal ownership from the beginning and sets students up to persevere through challenges (Kafai, Lee, et al., 2014).

Designing for Depth

Not only did we wish to ensure students were engaged but also learned deeply by providing rigor to all students as a type of equitable learning. Too often constructionist projects stay at what Blikstein and Worsley (2016) call the “keychain phenomenon” where students enjoy “low floors” to design but do not continue onward to the “high ceilings” possible with more advanced ideas and skills (Resnick & Silverman, 2005). To this end, the unit had introductory and complex e-textiles projects (Figure 1 and Table 1) that built on design, crafting, circuitry, and coding skills, each increasing in both difficulty and open-endedness.

Designing for Multiple Experiences

The design of the e-textile unit also provided multiple experiences in learning about design, crafting, circuitry, and coding skills through having students conceptualize and then implement four projects rather than just one complex project. This approach provided repeated opportunities for students to engage in practices such as debugging, revising, testing, collaborating, and designing for other users.

Designing for Audience

We further supported project designs with authentic audiences by having teachers display their own and students’ projects at the beginning of the unit, during the unit as a way to share peer knowledge (see next section), and at the end of the unit as a form of collaborative show and tell. Some teachers went further to encourage students to show their projects to other teachers at the school or put projects on display in school hallways and display areas. This made students’ projects transparent to each other for idea generation and also provided authentic audiences for students, a common principle in studio design education (Hetland et al., 2013).

Designing for Collaboration

Peer pedagogy, or students teaching each other, was another design principle of the unit in both intentional and emergent ways. We deliberately used pair programming during coding instruction moments and chose to make one project (the mural) collaborative at both a classroom and partner level. But we were also surprised to find from our research how often students’ helped each other in unstructured ways. When reporting on challenges on their individual final projects in their Year 2 portfolios, nearly one-fourth of students explicitly mentioned peer help as key to resolving bugs (see Jayathirtha, Fields & Kafai, 2018). Observations show even more frequent peer-to-peer help, encouragement, and support. Two things support this unstructured peer pedagogy in the unit. First, the physical structure of the classroom with students at small tables with shared supplies (scissors, thread, alligator clips, etc.) encouraged unstructured student collaboration. Student work (including errors) is visible and frustration is audible by sheer proximity. Second, teachers developed practices that support peer pedagogy, such as providing help to one student so that student could help others, connecting students to others who have expertise, and allowing student mobility in the classrooms, permitting them to get up and down and move around the room.

Designing for Productive Failure

Another goal of the unit was to support students in valuing the *process* of making projects, not just the final product. This meant finding ways to highlight mistakes and make them into learning opportunities rather than learning barriers. The teachers themselves developed several practices in this regard that we now explicitly model and name in professional development workshops (Fields, Kafai, Nakajima, Goode, & Margolis, in press). For instance, the teachers highlighted their own iterative practices of creation, including their own mistakes, errors, and less-than-perfect projects in front of the classroom. This allowed the teachers to self-deprecatingly model practices of revision and iteration and coach students on tips for dealing with this process. The teachers encouraged students to think that it was okay not to be perfect the first (or the second, third, fourth) time.

The teachers also showcased students' challenges, mistakes, and in-process projects. They did this in multiple ways. First, teachers would highlight mistakes for the entire class during project time. One teacher created a tradition of saying, "This is my favorite mistake of the day!" and then would show the mistake and ask the rest of the class for help in identifying what was wrong and why. Second, teachers had students highlight mistakes through personal journal entries, some of which we adopted formally in later versions of the curriculum. For instance, one teacher added a journal question after the completion of the wristband project that solicited challenges that students had faced: "Think about this week's project, what was the biggest challenge?" Students wrote their own reflections before sharing out ideas. These methods made students' mistakes into a form of shared classroom knowledge, foregrounding students as experts in the classroom, a key practice of equity-based and constructionist teaching principles that situates knowledge in the hands of learners and not just teachers.

Designing for Reflection

Honoring the role of reflection in constructionist learning settings, another key element of the curriculum involves supporting students in consciously thinking about their processes of learning and honoring mistakes and challenges that occur during that process. Drawing on practices of reflection already present in the larger ECS curriculum (namely short journal entries and class discussion), we intentionally expanded these by including *design notebooks* and *portfolios*. Students responded very positively to the portfolio, saying that it helped them to see how much they had learned and appreciating that they were graded not just on the final product but also on their process of learning (Lui et al., 2018). In Year 3 we increased the supports for the portfolio by encouraging more frequent practices of documenting and reflecting on mistakes throughout the entire unit and not just on the final project. We included taking regular photographs of unfinished projects as "exit tickets" on crafting days, and made more "design notebook" entries where students suggested tips for others or noted changes that they made.

Designing for Practicalities

We also designed for the practicalities of managing materials and students, improving this each year. Teachers of *Stitching the Loop* taught in regular computer science classrooms not set up for the messiness of crafting. Early on the teachers developed practices to *manage materials and set-up* including 1) Using lidded boxes to contain table supplies; 2) Initiating set-up and clean-up practices where one student per table would pick up a craft box and later take it back; and 3) Organizing student work in individual Ziploc bags and storing these within the craft boxes. We also worked with *manufacturers* to make it easier to purchase materials for the e-textiles unit. This involved simplifying the number of merchants to order from (to satisfy school administrations) and lowering costs. The development of new microcontrollers like the Adafruit Circuit Playground that already had multiple switches and sensors onboard further allowed us to steeply lower the per-student cost of the unit to about $40/student (instead of $60+/student). We also negotiated with the manufacturer to create student and classroom kits that were easy to order and organize, with the added benefit of offering teachers of the unit bulk pricing for additional classes they needed supplies for.

Design for Iterations

Finally, as with any constructionist venture be it tools or activities, we iterated through the various aspects listed above. For instance, in the first year of the unit we had six projects, but this became overwhelming to fit into the limited 8-week window available as an ECS unit. We identified overlapping skills between projects and cut two projects that did not significantly add to students' skills. In Year 2 implementation we found that the four projects were sufficient for students developing the knowledge needed to carry out the final project and the time required was much more manageable. Furthermore, we shifted from a test-based assessment to a portfolio-based assessment where students shared summaries of their projects, challenges and revisions that happened as they made them, and reflections on their learning overall.

Conclusion and Discussion

In ‘Mindstorms’ Papert (1980) outlined a bold vision of how computers could help children learn, launching the development of numerous programming languages for learners, the design of various computational construction kits, and the creation of learning communities. Nearly forty years later this vision is making a comeback around the globe, promoting coding and making inside and outside of schools. Success stories of the Scratch platform and community and the Maker Movement have demonstrated that millions of kids can be interested in programming and in making electronics together in afterschool spaces and activities. What does it mean for these activities to move back into the classroom with its focus on standards, curricula, and assessments within limited time periods and limited staffing?

Our guiding principles for designing a curriculum embrace constructionist ideas and approaches in creating anew the conditions where personal projects can flourish, students can support each other, teachers can become members of the learning community, and failure is seen as part of the process. In many ways, constructionist-oriented teachers and researchers have adopted these principles for a long time. In designing *Stitching the Loop,* we hope we have made them explicit so that other teachers and designers can adopt them for bringing constructionist activities to classrooms and promoting more equitable teaching and learning opportunities for students. Though afterschool, out-of-school, and online constructionist experiences have much to offer, we believe that classrooms provide unique opportunities to reach out to broader numbers of children and youth who may not take the initiative to step into those more informal experiences. Further, classrooms furnish circumstances that can support greater rigor and depth because of consistent attendance and dedicated time to projects.

In return we must of course consider the constraints of classrooms themselves, with the need to promote certain academic content and practices, limited staff, and physical and material constraints. Teachers report that *Stitching the Loop* has been a tremendous success with student engagement and preparation for more advanced computing courses. It provides a proven example that one teacher can work to support personalized project-creation with 25, 35 and even 40+ students. Projects with creative constraints, peer pedagogy, and process-based reflection all support depth of learning while legitimizing learners’ expertise and supporting interest-driven engagement. Robust professional development, building on the ECS model and educating in the way we hope teachers will educate their own students, is a key factor in ensuring the *design principles* are implemented fully.

Of course, challenges remain. Supply costs for the unit have become more reasonable but not all schools can afford them consistently. Inevitably, not all teachers will embrace the principles of the unit equally, resulting in inconsistent implementation. This means we need to support teachers beyond the first year or two of implementation now that the curriculum is ready for national release. In developing ‘Stitching the Loop,’ we illustrated how guiding principles need to apply to the design of construction tools and kits as well as to the constructionist projects and activities in which they are employed. Only then can we provide personally meaningful and equity-minded experiences to all learners.

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