Functional Aesthetics for Learning: Creative Tensions in Youth e-Textile Designs

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Abstract: Most research in programming and engineering focuses on students' understanding of functionality as a way to gage their learning, leaving aside aesthetic dimensions. In our work with the LilyPad Arduino, an e-textile construction kit with controller, sensors and actuators that can be embedded via conductive thread and programmed in fabric and garments, we examine how functional aesthetics can play a productive or sometimes unproductive role in learning. Drawing from observations and interviews with 35 high school youth that created e-textile artifacts, we identified three different approaches ranging from giving up on desired designs to making something functional or not finishing or getting a design to work because of unwillingness to give up on aesthetics. We see the third approach, finding a new design that both meets aesthetic desires and matches affordances of the technologies, as particularly promising approach and discuss how aesthetic dimensions can provide important connections in learning.

Introduction

Learning sciences research has made great strides in understanding learning and teaching science, mathematics, social sciences and language arts inside and outside of schools, developing modeling tools and learning environments, and promoting new methods for research (for overview see Sawyer, 2006). There are, however, a few fields such as arts education and aesthetics that have received little, if any, consideration, especially in regard to how they relate to STEM subjects. As Lemke (2010) recently noted, "by and large the use of emotionally and aesthetically appealing imagery, video, or simulations and games has been excluded from the teaching of science owing to a misplaced desire to portray science as a body of theory and fact, rather than as a human activity". These observations can easily be extended from science into other disciplines and to activities beyond the screen: namely, those aspects of digital media construction and design that dovetail with hands-on crafts, physical construction and design, as well as material play. In this paper we focus on learning with a new type of tangible, programmable media called electronic textiles (e-textiles hereafter).

E-textiles include designs of programmable garments, accessories, and costumes (Post, Orth, Russo, & Gershenfeld, 2000). Such designs can incorporate elements of embedded computing for controlling the behavior of fabric artifacts, novel materials such conductive fibers or conductive Velcro, sensors for light and sound, and actuators such as LEDs and speakers, in addition to traditional aspects of fabric crafts. The making of e-textiles engages both functional and aesthetic aspects that have been described as "the concept of merging a fashionable technology object deemed aesthetically pleasant with technically enhanced functionalities" (Seymour, 2010, p.10). While Seymour also focused on the production of new fabrics, techniques and technologies, we were particularly interested in the role of functional aesthetics in learning to work with an e-textile construction kit called the LilyPad™ Arduino (Buechley, 2006). The LilyPad Arduino belongs in the family of material computational construction kits that makes these technologies accessible to novice designers as the Lego™ Mindstorms did for robotics constructions in school programs. But e-textiles do so within context of soft computation where "the design of digital and electronic technology is composed of soft materials such as textiles and yarns, as well as predicated on traditional construction methods to create interactive physical designs" (Berzowska, 2005, p. 67).

This work is part of a larger research project aimed at understanding creativity in computation (Kafai, Peppler, & Buechley, 2009) in which we conducted a series of e-textile workshops with high school youth during 2010-2011. While our main interest was in understanding how youth learn about electrical circuit design and programming, we also wanted to know how the aesthetic features of their e-textile projects influenced their design decisions and progress. Our intention was to attend to the *process* of creating aesthetic and functional artifacts and to develop a framework for how aesthetics related to learning (or not) while also serving to promote personal relevance through connecting attractiveness to technology. Our data comes from observations, field notes, video records of workshop interactions, analyses of e-textile artifacts designs and realizations, and interviews with high school youth about their experiences and artifacts. We analyzed design decisions by 35 high school freshmen and women creating e-textiles over four weeks, attending to the times when their aesthetic ideas interacted with functional requirements in shaping their designs. We address the following research questions: How do aesthetics influence the design of e-textile artifacts? How do students' aesthetic visions relate to their learning to make e-textile projects? In the discussion we will consider how functional aesthetics for learning can also be expanded into other digital media projects.

Background

The arts and sciences have long been connected in the scientific (if not the public) imagination. In the past, scientific tools were not intended simply as measurement devices, but also as aesthetic objects: "as occasion for artistic ingenuity and whimsy… possibilities for blending art and instrumentation design" (Resnick, Berg & Eisenberg, 2000, p. 24,). Science professionals often derive aesthetic pleasure in their work: Mathematicians describe math as poetry, computer scientists attend to beautiful and simple solutions, and physicists pronounce theories and equations to be beautiful (Girod, 2007). Chamberlain (1987) argues that in both art and the science, deep observation reveals new ideas and suggests that aesthetics is an integral part of *discovery* in the sciences (Chamberlain, 1987). Furthermore, Lemke (2010) goes so far as to consider aesthetics part of a scientific habitus that includes positive, affective dispositions toward conventional scientific technologies, media genres, and styles of representation within specific science disciplines. In her decades long studies of physicists, Traweek (1995) describes "an elaborate aesthetic and moral discourse among high energy physicists" where machines, software, data, and laboratories are described with adjectives like sexy, cute, beautiful, constant, and ordered." She argues that scientists have aesthetic values in the images and tools that they use, recounting a time when, "[O]nce I watched a group of physicists gazing at a book of images of fractals; with each turn of the page came a soft chorus of pleasured sounds" (Traweek, 1995, p. 212). Appreciating the aesthetics of scientific phenomena and representations is an important part of what it means to be enculturated into science.

In K-12 science and technology education, aesthetics is most often viewed as extraneous to core academic learning, "a misplaced desire to portray science as a body of theory and fact, rather than as a human activity" (Lemke, 2010). At best it is seen as a motivating function, something that promotes interest and identification in science and technology. For instance, several studies have found that both positive and negative aesthetics can reveal engagement and promote identification with science topics inside and outside of school (Barton, Tan & Rivet, 2008; Brickhouse, Schultz, & Lowery, 2000; Jacobson & Wickman, 2008). There is a small body of research that has examined aesthetics in relation to learning and teaching of science (Flannery, 2006; Wickman, 2006) focusing on social, cultural and personal aspects. A few studies of classroom teaching where aesthetic ideas about science were conveyed have also shown promise for furthering learning. Hadzigeorgiou (2011) found that students retained more ideas, asked more questions, and wrote more in voluntarily kept science journals when aesthetics was consciously included in the science curriculum. Girod, Twyman, and Wojckiewicz (2010) also found that a focus on aesthetics promoted better retention in later assessments. In these studies, aesthetics is seen as having a sense of wonder (Hadzigeorgiou, 2011), becoming aware of "powerful science ideas" (Girod et al., 2010), or having transformative experiences akin to Dewey's writing on the power of aesthetics (Pugh, 2011).

Our approach in examining aesthetics in the context of e-textile designs builds on these studies but does so paired with learning to design with a technology, particularly in the areas of engineering (designing and testing electronic circuits) and programming (turning circuits on and off – e.g., making lights blink). While some studies have begun to look at the relationship between aesthetics and functionality in students' technological designs, they have largely focused on the final product (is it attractive?) rather than the process, and have attended mostly to the motivational aspects of making something aesthetic. For instance, researchers found that when students pay attention not only to functionality but also to aesthetics of robotics artifacts, they have a much stronger connection to their creations (Resnick, Berg, & Eisenberg, 2000) as well as recruit and retain a larger group of students (Rusk, Resnick, Berg & Pezella-Granlund, 2007). In this study we focus on aesthetics as more than a tangent: students' e-textile designs are driven by functionality as well as aesthetics in their personal choices and thus become a context for learning. In particular, we want to include the material or physical side as scientists such as Nobel prize winner Barbara McClintock have argued for physical touch as an important aspect of inquiry (Keller, 1983). Here we suggest that the tension between designing something aesthetically pleasing that is also functional is a creative tension, one that promotes new learning *because* the aesthetics can push the design and vice versa.

Context & Methods

The primary context of the study took place in e-textiles workshops led with 9th grade (14-15 year-old) high school students at a local science museum. We led a series of three workshops, each roughly one month-long with weekly two-hour meetings. In the workshops, a total of 35 students learned how to design and create their own e-textiles projects, beginning with aesthetic drawings, followed by circuit schematics, sewing/crafting of designs, and programming. The series culminated in the third workshop where 16 students, 15 of which had prior experience making e-textiles from another workshop, completed finished e-textiles that had at least 2 blinking lights that they had sewn and programmed. Since students finished the most complex work in this final workshop, it serves as the focal point for our analysis of the relationship of functional aesthetics to learning in e-textiles.

Materials

All students had access to the *LilyPad Arduino* construction kit (Buechley & Eisenberg, 2008) that enables novice engineers/designers to embed electronic hardware into textiles (see: http://web.media.mit.edu/~leah/LilyPad/). In addition, we had various caps, t-shirts, gloves, cotton bags, fabric and felt pieces. Some students also brought their own clothes or objects for e-textile designs. The LilyPad is a set of sewable electronic components, including a programmable microcontroller and an assortment of sensors and actuators that allows users to build their own soft wearable computers. Users sew LilyPad modules together with conductive thread instead of traditional tools like insulated wire and soldering techniques. To define the behaviors of the project, users employ the popular Arduino or ModKit development environments, enabling them to program the LilyPad microcontroller to manage sensor and output modules (like LEDs) employed in their designs.

Data Collection and Analyses

Across all workshops we gathered video recordings of students working together, field notes by at least two independent researchers, final interviews with students, and weekly photographs of students' designs. As our expertise in how to help students create e-textiles grew, our data collection became better defined. We conducted iterative analyses after each workshop, reflecting on what students struggled with and what strategies helped them succeed. This reflection led us to focus our data collection in the third and final workshop on students' processes of design, from their original ideas through their learning about the affordances of the LilyPad, LEDs, and conductive thread, and to their final designs. To gather this data two researchers collaborated to write detailed, descriptively rich field notes on each student's design progress each week accompanied by multiple photographs per student. This allowed us to follow all students consistently through their design process, supplemented by final interviews where we asked students to explain how their project had changed from their original ideas to finished product, what they were most proud of, what they struggled with, and what they felt they had learned.

Analysis was completed in two steps. First, we conducted a two-step open coding across all of our data (videos, field notes, interviews, photographs) based on grounded theory (Charmaz, 2000) focused on what students struggled to learn. From this coding we noticed two categories of learning related to aesthetics that were present across all workshops: working out the polarized orientation of LEDs for efficient circuitry and using the LilyPad to greatest effect in both placement and choices of circuits. With this insight we sought to understand how students' growing knowledge of polarized circuitry and the affordances of the LilyPad related to the aesthetics of their designs. To do this we conducted a second phase of analysis, developing case studies for all 16 students in the third workshop that detailed their original ideas, the challenges they faced, their decisions at these challenges, and the next cycles of ideas-challenges-decisions until the design process ended with their final product at the end of the workshop. We also took into account interviews and reflective statements about what they were most proud of as well as how others responded to their projects. Across the case studies we looked for common issues related to aesthetics and learning.

Findings

In this section, we first present one of the 16 case studies for which we mapped out the design process of students' projects, including their original ideas, challenges, decisions and resolutions, and final products. The case study focuses on one student's design process and highlights in detail how aesthetics played a role in her design decisions and learning. Then we report on common relationships between aesthetics and circuitry and aesthetics and programming found across all cases.

The Unfolding of Amari's Shining Star

We begin by describing the design process of one girl, Amari, whose project changed significantly in scheme if not in essence from the beginning to the end of her two-workshop design process. Amari told us that when she first came to the workshop, she thought it would be really confusing and that she wouldn't like it. However, she grabbed onto the crafting aspect and was allowed to start by simply cutting a star out of white felt and sewing it onto a pink rectangle of felt: "I just sewed it onto felt and then I was like, 'It's time for lights and techie stuff,' and then slowly I started to understand it' *(May 27, 2011, Video)*. Her initial idea for her project was to make something simple, a five-point star with LEDs on each point.

> "Okay, well I decided to do this because, well, I wanted to make something that was kind of bright so I just chose the pink color and I didn't want to do something really complicated like other people did. I wanted to do something simple, so I just did the star and, um, I just put a

> star on the pink and I decided to make each of the points light up 'cause that'd be really, what do you call it, bright I guess."
> *(May 27, 2011, Video)*

Here we see some of her original aesthetic desires – a white star on a bright pink felt background, with each LED lighting up. However, actualizing these ideas was not trivial for Amari; even though she felt her design was simple, she had to re-design and even re-sew parts of it several times.

One challenge that she and many students faced at the beginning was how to layer the positive and negative connections between the LEDs over their aesthetic drawings, which usually had no considerations of electrical connections. Amari started with a diagram of a star with five LEDs where the positives and negatives of the LEDs connected with each other but nothing else, not a LilyPad or a battery (see the large pencil star on the left of Figure 1). With coaching, she drew another, smaller diagram with a circular LilyPad inside the star and the positive ends of the LEDs connecting to different pins on the LilyPad (see smaller star on the left of Figure 1 and our schematic of this diagram on the right of Figure 1). This was a significant improvement on her earlier design, but it still lacked a connection between most of the negative sides of the LEDs and the LilyPad: only two negative sides were connected to each other and to the negative pin of the LilyPad in her drawing.

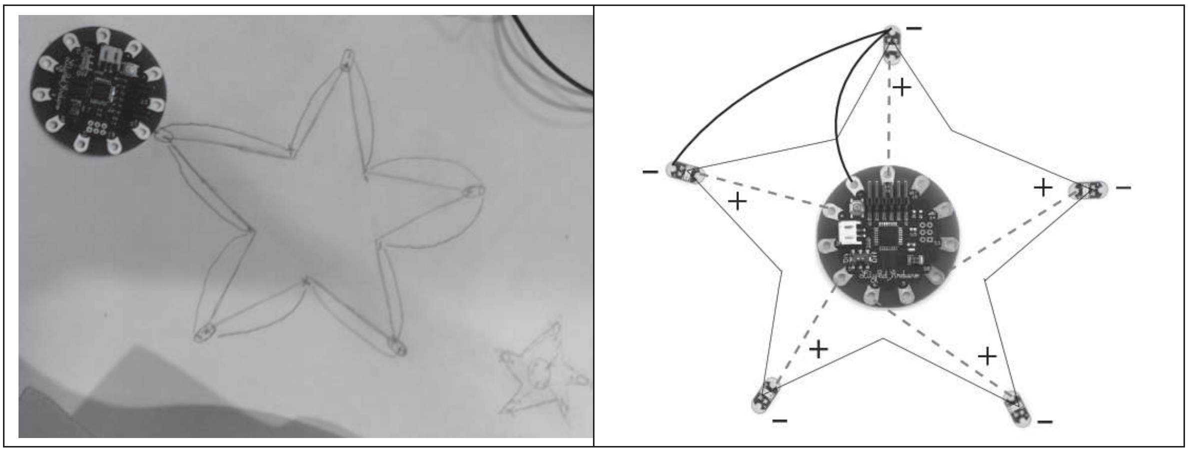

Figure 1. Amari's initial designs (left), with the large penciled star her first design and the small penciled star her second design, and our schematic diagram of her second design (right).

Amari's circuitry design became more sophisticated through the process of sewing on the LEDs. These design changes were influenced both by her sense of aesthetic and by her growing understanding of circuitry and the affordances of the LilyPad. First, Amari realized that she could connect all of the negative sides of the LEDs together by sewing a circle around the points of the star. She described this unplanned change to us as both a convenient and "cool" looking solution:

> My original design? I didn't know that I'd be putting the negatives all in a circle which is a really cool effect but I didn't think that I'd be doing that first. Um, I just thought I'd do each of the negatives going into a different thing [pin]… I thought it'd save me more work so I decided to do that [the circle] and, it did. And then I decided to make the positives go around in like little swirls or something and that also made it fun and easy.
> *(May 27, 2011, Video)*

Compared to Amari's original design with, as she put it, "random lines going to random places," or her second design where only some of the negative sides were connected to anything, this third version was a completely functional solution (see left side of Figure 2). Connecting all of the negative sides of the LEDs in a single line to the hardwired negative pin on the LilyPad was a simpler circuit that was also more convenient to sew as Amari did not need to change, cut, or tie the thread in the continuous negative line. Yet while it was a functional solution, it was also an aesthetic one as well. Amari saw the circle around the star as "cool effect" and later magnified this effect by cutting a larger circle of pink about two inches outside of the conductive thread circle.

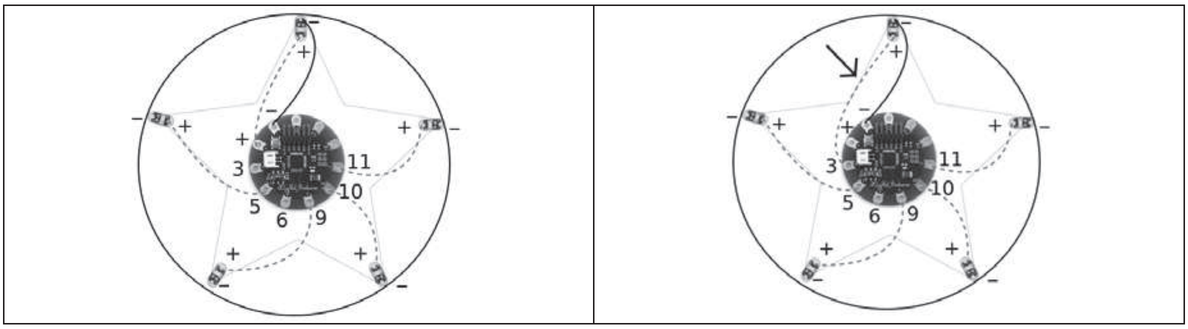

Figure 2. Changes in Amari's sewn designs. Left, she connected the top LED to the hardwired positive and negative pins of the LilyPad. Right, she re-sewed the top LED to the #3 pin to computationally control it.

After her project was sewn, computational considerations led Amari to alter her project. First, once she programmed the LEDs to turn on and off, she realized the downside of connecting an LED to both the hardwired negative *and* positive pins on the LilyPad: she had no computational control over that LED (the top LED in the schematics in Figure 2) and could not make it blink at all. She told us, 'I know that you told me it would always be on and I did it anyway, but I want to re-do it,*' (May 25, 2011, Field Notes)*. Amari ripped out the stitches of one of her conductive lines and re-sewed the positive side of the LED to a number pin on the LilyPad (#3) that she could manipulate through programming. This design change, shown between the two schematic diagrams in Figure 2, while minor, shows Amari's developing understanding of the affordances of the hardwired and programmable pins on the LilyPad. Second, Amari altered her initial computer program that made the LEDs blink to a much higher level of program where the LEDs faded. Motivated to produce a particular aesthetic fading effect in the LEDs of her star, she came in for a special session during her lunch hour to learn how to use variables and embedded loops in code in order to create a fade effect. This was a big step in learning for Amari, who said that before the workshops she had no idea how a computer worked and was intimidated by the technology.

We have illustrated in detail the design changes in Amari's e-textile project to show how they reflected her increasing understanding of circuitry and programming while being largely motivated by her aesthetic goals. The conductive circle connecting the negative sides of the LEDs in her star, suggests at least one instance where aesthetic desires worked alongside growing understanding of circuitry to make both an attractive and simple solution. In the instances of her physically changing the circuit of one LED from a hardwired to a programmable pin and her learning to create a fading effect through code, we can see how her aesthetic vision for her project motivated deeper learning of circuitry and programming. Here we have provided in detail the changes in design of Amari's e-textile star, but below we summarize the themes we found across all 16 case studies of students' designs, for which we conducted equally detailed analyses.

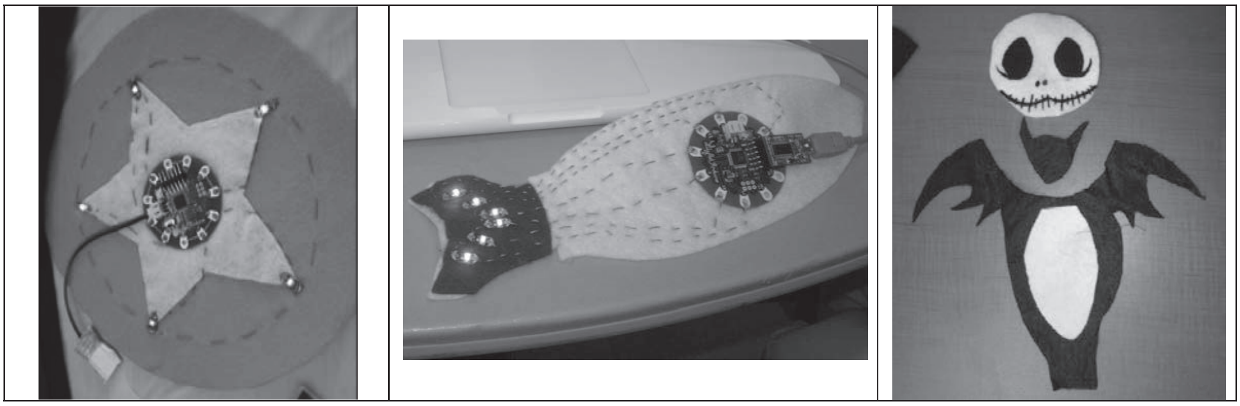

Figure 3. Completed E-textiles. *Left*: Amari's final star; *Middle*: Jackson's rocket, *Right*: Jaylee's Jack Skellington.

Aesthetics and Deepened Circuitry Learning

Amari's design process illustrates a common relationship between aesthetics and learning to design sewn circuits that occurred throughout the data. Across 15 of our 16 cases students re-designed circuits with aesthetic reasons driving their revisions. This usually happened for a few reasons. First, as students learned about the polarization of LEDs and thus the polarization of circuits, they modified their circuitry designs in ways that, like Amari's star, took into account an eye-pleasing form as well as ease of creation. This includes learning about the affordances of parallel and independent circuits. Parallel circuits allow for much easier crafting and lay out because both the positives and the negatives of the LEDs can be connected in two continuous polarized lines. However, they do not allow for computational flexibility. Depending on the students' desires, they altered their designs. Second, as they realized the differences between hardwired and programmable pins on the LilyPad, they often changed their design, as Amari did, to provide the opportunity for more computational flexibility. Sometimes this extended to understanding the differences of analog and digital pins on the LilyPad, which had divergent affordances for reading data from sensors (analog) or fading (digital). Finally, as circuits were realized in physical form on fabric, students amended designs to take into account practicalities like the location of the LilyPad relative to the LEDs or other electrical elements like sensors and overlapping circuit lines.

More often than not, multiple circuitry issues intersected to create tensions between functional and aesthetic designs. For instance, Jaylee wanted to create the head of Jack Skellington (see Figure 3, right), a lead character in Tim Burton's *The Nightmare Before Christmas*, with two LEDs in each of Jack's two eyes. In working through her design, she decided that a single parallel circuit would be best because she wanted the eyes to light up the same way every time. However, she also wanted the head to be mobile – not attached to a backing of felt – so that it could be pinned to a backpack, a jacket or other accessories. To do this, she decided the LilyPad needed to be on the back of Jack's head, and developed a complex set of layers of felt to insulate the positive and negative lines of her otherwise simple 4-LED circuit. In another case, Silas began with a complex design of twisting ribbons that had more than 30 LEDs attached. As he tried to map out the positives and negatives of the polarized lines to the LilyPad, he eventually settled on 8 sets of parallel circuits with 2 LEDs, each on its own ribbon length. However, he had to re-design his e-textile project again when he realized that there were only 9 programmable pins on the LilyPad, so he developed a similar solution to Amari in connecting the negative lines of multiple circuits together and sewed that to the hardwired, negative pin. These cases illustrate how students' aesthetic goals interacted with the practicalities of the technology they were using (LilyPad, LEDs, conductive thread) and their growing understanding of these technologies and circuits in general in the realization of their designs.

Aesthetics & Coded Lighting Effects

In addition to affecting students' circuitry designs, aesthetics also played a role in most students' learning to program. The primary reason for this is because programming was the way to achieve particular lighting effects in the e-textiles students designed. In the 8-hour workshop, there was relatively little time at the end to do more complex lighting effects, and the 10 of 16 students (of 16 total students in the workshop) who wanted different effects had to spend extra time outside of the workshop learning more programming than was required simply to turn their lights on and off. Some students wrestled to create multi-step lighting effects for projects with several circuits. Consider Jackson who created a rocket with six LEDs in the tail that he eventually programmed to blink in timed stages: two middle lights on [delay] next two lights on [delay] outside lights on [delay] all off [long delay] (Figure 3, middle). Jackson and others spent extra time experimenting with delays and order of lights to design this effect. For another instance consider Corbin who had two circuits with four LEDs each that he wanted to make blink on and off in turn (left side on then off, right side on then off). However, because one of the circuits was connected to two programmable pins, he struggled with the issue of control flow in his programming. He eventually learned to turn the negative sides of both circuits on at the beginning of his program, then in a "forever loop" to turn the positive sides on and off. Though these may seem like simple concepts to experienced programmers, it was a very challenging concept for nearly all of the novice students in our workshops to learn as they had to coordinate the design of code and circuits.

Further, five students went significantly deeper into programming in order to use sensors or make fading effects in their projects. Using sensors in a project required learning to use conditionals in programming. For instance, Darryl created a bag with a light sensor on the handle such that when someone picked up the bag (making the sensor completely dark), the lights turned on, and otherwise they were off. To create a fading effect students had to learn to use variables and embedded loops in their code. Interestingly, three girls who had expressed that programming intimidated them came in during lunch one day to learn to do fading effects (including Jaylee and Amari whose projects are shown in Figure 3). In sum, the desire for an attractive lighting effect motivated many students to learn more complex coding.

Discussion

While many who have striven to connect aesthetics to science or technology education have focused on the importance of aesthetics in the final product, in this paper we have attended to the *process* of creating an aesthetic and functional product. We analyzed design decisions by students creating e-textiles over four weeks, concentrating on the times when their aesthetic ideas interacted with functional requirements in shaping their designs. We found that aesthetics played a role in almost every step of design, from the students' original ideas to their development of explicit circuitry designs, from their physical construction of the project to their final coding of lighting effects. In each step the students' aesthetic vision interacted with the practicalities of construction, the necessities for functional circuits, and the affordances of the LilyPad microcontroller and the polarized LEDs. In every case, students' designs for their projects changed as they developed understanding of circuits, coding, and the technologies they were using, but throughout the process aesthetics continued to play a role even if the final product looked significantly different from their original drawings.

Further, in most studies of learning by design, there is a penchant for considering aesthetics as attractive and personally motivating without attention to how the integration of aesthetics into a project can become a tool for learning. While we too found that making an aesthetically pleasing e-textile project was motivating for students, aesthetics went beyond motivation to influence their learning of circuitry and programming. By looking at the step-by-step process of designing and re-designing e-textile projects, our analysis demonstrates that students' aesthetic visions almost always promoted their learning in these areas. In particular, we noted how aesthetics played a role in fashioning more efficient and often more intricate circuitry designs as well as more challenging programmed lighting effects. In many cases, because of their aesthetic motivations for how their project would look and act, students sought out additional help, pressed through new challenges, and spent additional time outside of the workshop in order to learn more about circuitry and programming so that they could achieve a pleasing project.

However, we do not mean to imply that simply making e-textiles project will always promote positive creative tensions between aesthetics and technological design. Rather, our experiences across workshops suggest that the local social context for making such a project must promote aesthetics and help students to create attractive projects that are also within their realm of reachable expertise. In our first workshop, when we knew less about how to help students design e-textile projects, some students created projects that were functional (i.e., the LEDs lit up) but not aesthetically pleasing to them, and they gave these projects back to us because they had no interest in keeping them. In other cases, some students were unwilling to alter their original elaborate blueprint designs according to the affordances of the LEDs and LilyPad and never even reached the point of constructing a project. In contrast, in our third workshop we successfully combined concrete, functional goals for each workshop (e.g. sew two lights, code two lights) with a focus on aesthetics. We paid special attention to prioritizing aesthetics in their projects and helping them translate their ideas into projects that were within or just beyond the bounds of what they could learn in the workshop.

In this paper we tackled the issue of how aesthetics relate to learning in the context of e-textile projects, expanding our understanding of learning and creative imagination. In his discussion of the development of creativity in adolescence, Vygotsky (2004) argues that mastery of tools is as important as the development of creative imagination:

> First, for adolescents the mere exercise of creative imagination is not enough. A drawing done any old way fails to satisfy. To embody his creative imagination an adolescent needs to acquire special professional artistic skills and abilities… We thus see the problem in all its complexity. It has two parts: on the one hand, we need to cultivate creative imagination; on the other hand, a special culture is needed for the process of embodying the images created by imagination. (p. 85)

Thus according to Vygotsky, students need to develop mastery of technology (in our case, e-textiles) alongside their creative imagination. He suggests that doing so in a community that specializes in the particular techniques and uses of technology related to a specific kind of art can provide a zone of proximal development for the adolescent. Thus learning develops alongside aesthetic or creative imagination. Our analysis of students' design processes demonstrates this, showing what they learned through the process of embodying their aesthetic ideas in their e-textile project. Because e-textile designs involve circuits and programming, this learning developed alongside the creation of their aesthetic projects. Notably, we did not explore the motivations behind students' aesthetic ideas, but this is a ripe area for further analysis as their projects showed many of their personal interests or experiences. Students often used their projects to reflect their interests in popular culture using symbols from anime, comic strips, or movie series, geek culture especially in designs that showed off the technology, feminine culture with hearts or stars or indicating their family membership (e.g., gifts for mom, dad, brother, or sister). Future analysis is needed to understand how students' e-textile projects bring together personal, peer, and pop culture values while also providing a context for learning academic skills such as circuitry and programming.

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Acknowledgments

This work was supported by a collaborative grant (0855868) from the National Science Foundation to Yasmin Kafai, Leah Buechley and Kylie Peppler. Any opinions, findings, and conclusions or recommendations expressed in this chapter are those of the authors and do not necessarily reflect the views of the National Science Foundation or the University of Pennsylvania. We thank Joyce Wang for comments on earlier versions of the paper.