Boys' Needlework: Understanding Gendered and Indigenous Perspectives on Computing and Crafting with Electronic Textiles

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ABSTRACT

We draw attention to the intersection of race/ethnicity and gender in computing education by examining the experiences of ten American Indian boys (12-14 years old) who participated in introductory computing activities with electronic textiles. To date, the use of electronic textiles (e-textiles) materials in introductory computing activities have been shown to be particularly appealing to girls and women because they combine craft, circuitry, and computing. We hypothesized that e-textiles would be appealing to American Indian boys because of a strong community-based craft tradition linked to heritage cultural practices. In order to understand boys' perspectives on learning computing through making culturally-relevant e-textiles artifacts, we analyzed boys' completed artifacts as documented in photographs and code screenshots, their design practices as documented in daily field notes and video logs of classroom sessions, and their reflections from interviews guided by the following research questions: (1) How did American Indian boys initially engage with e-textiles materials? (2) How did boys' computational perspectives develop through the process of making and programming their own e-textiles artifacts? Our findings highlight the importance of connecting to larger community value systems as a context for doing computing, the importance of allowing space for youth to make decisions within the constraints of the design task, and the value of tangible e-textiles artifacts in providing linkages between home and school spaces. We connect our work to other efforts to engage racial and ethnic minority students in computing and discuss the implications of our work for computer science educators designing computing curricula for increasingly diverse groups of students, especially as pertains to the emerging field of culturally responsive computing.

Categories and Subject Descriptors

K.3.0 **[Computers and Education]:** General

General Terms

Human Factors

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Keywords

Electronic textiles; Indigenous peoples; American Indian/Alaska Native; gender; K-12; broadening participation in computing

1. INTRODUCTION

Most of the conversations about broadening participation in computing have focused on gendered differences in participation [11, 40]. Much less attention has been paid to the equally important but far more complicated intersections of gender with race and ethnicity [41]. Discussions around broadening participation often assume that boys and men are dominant in computing circles, effectively erasing the experiences of males from non-dominant racial and ethnic groups within a given context. In the United States, for instance, African American and Latino men each represent just 6% of the computing workforce and American Indian/Alaska Native men represent less that 2% of the computing workforce [46]. The situation is equally troubling when we examine the participation of minorities in computing activities in K-12 settings [16, 34]. In this paper, we want to draw attention to the intersection of race/ethnicity and gender by examining the experiences of a middle school class of American Indian boys who participated in an introductory computing activity with electronic textiles. While American Indian boys represent a small subset of the U.S. population, we believe their experiences provide insight into engaging non-dominant racial and ethnic groups in computing across a multiplicity of contexts. In particular, this paper has implications for engaging Indigenous populations throughout the world [17], especially those with strong heritage craft traditions [29].

The use of electronic textiles (e-textiles) materials in introductory computing activities has been shown to be particularly appealing to girls and women because of their hybrid nature and the strong connection to craft [7]. E-textiles construction kits like the LilyPad Arduino kit [8], consist of a small, sewable microcontroller and a variety of sensors and actuators. These sewable, electronic components are affixed to fabric and connected to one another using conductive thread. The completed circuit is then hooked up to a computer via a USB cable and programmed, resulting in a small, wearable computer. We hypothesized that, in spite of gendered cultural histories surrounding craft practices as "women's work" [48], e-textiles would appeal to American Indian boys because of a strong community-based craft tradition linked to heritage cultural practices and Indigenous Knowledge Systems [5, 13, 27]. The community where the research took place is known for its pottery and basketry. Though few individuals in the community still practice these crafts, the designs are finding new homes in graffiti art and in apparel, such as the desert collection designed for Nike by community-member Dwayne Manuel [37]. These shifts are an important reminder that culture has a fixed, enduring quality but is also adaptable over time. It is this adaptable nature of cultural craft practices that we drew upon in designing a culturally responsive, introductory computing activity employing e-textiles.

We focus on the intersections of gender, craft, computing, and culture from boys' (rather than girls') perspectives. We examine the experiences of ten American Indian boys (12-14 years) engaged in a three-week, culturally responsive e-textiles unit as part of their Native Studies class. In order to understand boys' perspectives on learning computing through making culturally-relevant e-textiles artifacts, we analyzed their completed artifacts as documented in photographs and code screenshots, their design practices as documented in daily field notes and video logs of classroom sessions, and their reflections from interviews guided by the following research questions: (1) How did boys initially engage with e-textiles materials? (2) How did boys' computational perspectives develop through the process of making and programming their own e-textiles artifacts? Drawing upon three case studies from the larger data set, our findings highlight the importance of connecting to larger community value systems as a context for doing computing, the importance of allowing space for youth to make decisions within the constraints of the design task, and the value of tangible e-textiles artifacts in providing linkages between home and school spaces. In our discussion, we highlight the broader implications of our work for computer science educators who are designing computing curricula for increasingly diverse groups of students, especially as pertains to the emerging field of culturally responsive computing.

2. BACKGROUND

Our focus on American Indian boys' perspectives on computing contributes to larger efforts to broaden participation. Recent research suggests that, more significant than a "participation gap" may be actually be the "identity gap" where young men of color struggle to reconcile their ethnic and academic identities [45] and are unable to see themselves taking on the identity of a "scientist" [52]. One potential solution is to develop computing activities with a strong connection to boys' multiple identities, including their ethnic identities [16, 28] Here culturally responsive approaches have been known to successfully bridge the "identity gap" by connecting the cultural practices of particular groups to mathematical and computational principles [20].

One of the best-known examples of culturally responsive computing is the Culturally Situated Design Tool, designed by Eglash and his colleagues [19] where, for instance, Shoshone beadwork is mapped onto a Cartesian coordinate system and learners design on a Virtual Bead Loom. Another example is the game design curriculum created by Lameman and her colleagues [39] for use with First Nations students in Canada that was based on traditional storytelling practices. Within each of these approaches, there is some level of cultural affirmation and/or critique built into either the tools themselves or the curricula [21]. This means that when youth engage in culturally responsive computing activities, they are engaging in identity work and develop what Eglash & Bennett [18] have called "design agency," the practice of working out one's identity within the technical constraints of the design tool and the environmental constraints of the space and place where the activity is situated.

In our work, we are building on these important ideas around culture and identity for making computing accessible and extending them into culturally responsive open design [34]. Culturally responsive open design connects community cultural practices with more open-ended design tools whose reach extends beyond the screen. Culturally responsive open design with e-textiles materials also creates a rich space for exploring the intersections of gender and race/ethnicity in computing by incorporating the distinct, gendered cultural histories associated with craft and engineering practices [47]. Rather than attempting to "unlock" the existing clubhouse of computing [39] with its focus on games and robotics, learning with e-textiles introduces computing through arts, crafting, and textiles. By design, e-textiles materials draw upon a hybrid foundation in crafting, engineering, and computing. Through this purposeful mashup of old and new materials and high and low technologies, e-textiles challenge and critique distinct cultural and epistemological foundations, including the strongly gendered (and often racialized and colonized) histories of crafting [48] circuitry design [44] computing [22], and technology writ-large [2, 47].

Like many other introductory computing curricula that provide a context for computing [3, 4, 15, 24, 36, 42, 49, 54] engaging learners with e-textiles materials develops computational thinking skills [53]. Specifically, we draw upon Brennan and Resnick's [6] framework for studying and assessing computational thinking, which encompasses learning computational concepts (sequences, loops, etc.), engaging with computational practices (remixing, for instance), and developing computational perspectives. Computational perspectives, or worldviews that designers develop as they engage in digital media [33], connect to a core concern in broadening CS participation that focuses on learners' perceptions of computing, where they see applications for computing, and how they see themselves within the field and future careers. When researchers ask about students' perceptions of computing [14, 55], they often hear an assortment of statements such as "being boring or tedious," "only for smart students," "antisocial," or "lacking creativity." The classroom implementation we conducted affords us the opportunity to re-examine these perceptions because of the particular positioning of e-textiles within a larger computing culture.

Brennan and Resnick [6] identified three types of common computational perspectives that learners developed through programming interactive digital media: (1) expressing, (2) connecting, and (3) questioning. Expressing refers to the ability to create something that allows for self-expression through computation. Connecting emphasizes the value of making something computationally in collaboration with others and for an authentic audience (as opposed to just a teacher who will evaluate the assignment). Questioning highlights learners' abilities to ask questions of and with technology. The development of these perspectives about computation is important because it marks a shift from viewing technology as something to be consumed to something one can harness as a tool for self-expression, relationship building, and democratic participation [30]. In Indigenous communities where electronic technologies are often seen as a threat to the persistence of heritage craft practices, Native languages, and other aspects of culture, the development of computational perspectives is an especially rich, but contentious, space for exploration.

3. METHODS

3.1 Participants

The participants in our study were ten eighth grade American Indian boys (12-14 years) who attended a charter school on tribal lands located just outside of Phoenix, Arizona. We call the school Eagle High School (a pseudonym). The boys participated in a three-week e-textiles unit as the culminating project in an elective, gender- segregated Native Studies class. The students reflected the demographic of the school, which was almost entirely American Indian (99%), with slightly less than half of students (46%) eligible for free or reduced lunch. Prior exposure to computing was limited to general technology use. Most of the participants had cell phones or tablets and played video games for entertainment but, like youth elsewhere, they had little sense of what computing entailed and who could or could not do it.

3.2 E-Textile Design

The e-textile design activity described here focused on making "human sensor" sweatshirts [32] using the LilyPad Arduino construction kit (see Figure 1) [8]. This kit enables novice makers to embed electronic components into textiles and consists of a sewable, programmable microcontroller and a variety of sewable sensors (e.g., temperature sensor, accelerometer) and actuators (e.g., LED lights, sound buzzers). Sensors and actuators are sewn to ports (holes that can be sewn through) on the LilyPad using conductive thread, which acts like the wire in more traditional electronics projects, and is knotted to secure a particular connection. When these components are sewn together using conductive thread and then programmed, they become a small, wearable, student-built computer. In order to program the LilyPad Arduino, either the Arduino or Modkit [43] development environments were used.

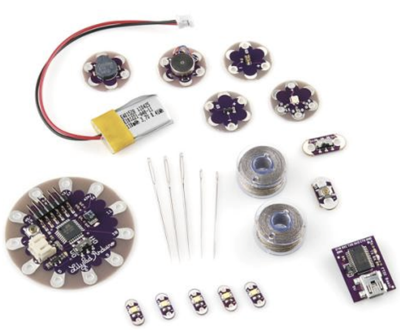


Figure 1: LilyPad Arduino kit

The activity was designed in consultation with the Native Studies classroom teacher and the community's Cultural Resources Department. After a quarter spent talking about community stories and their connections to place, students made e-textile designs connected to the elements (fire, water, earth, etc.) and to places that were of significance to local Indigenous communities. One goal was that making a light up, wearable versions of natural phenomena and significant local places would reinforce what students had already learned about living in the desert environment through the telling of community stories and perhaps spark larger community-level conversations when students took their projects home. Another goal was that students would learn something about computation and its connections to culture through the process of designing and making e-textiles. Students were asked to design and make e-textile patches comprised of a culturally-relevant aesthetic design, a LilyPad Arduino, at least two LED lights, and two metal snaps attached to the negative ground and an analog port respectively. These snaps connected to snaps on hooded sweatshirts that were pre-"wired" with conductive fabric patches on the cuffs that connected to metal snaps on the front of the sweatshirt. When a student's e-textile patch was connected to the snaps on the sweatshirt, it created a "human sensor" e-textile project (see Figure 2). In a "human sensor" project, the two conductive fabric patches on the cuffs of the sweatshirt function as a sensor to measure resistance from the human body when touched simultaneously. This adds a dimension of computational complexity to students' e-textile projects. In a longer workshop, students would have "wired" the hoodies themselves but, given the time constraints, the conductive fabric patches and conductive fabric "wiring" that connected the cuffs to the snaps and, by extension, to the LilyPad Arduino were pre-ironed. In addition to the added degree of computational complexity, if the human sensing components of the hoodies are wired identically, the sweatshirt wearers can then be united in a circle and all of the e-textile designs should light up, highlighting the importance of relationships between individuals and between elements within an ecosystem.

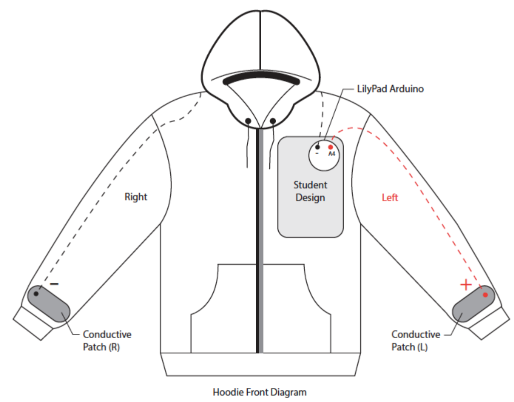


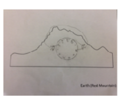
Figure 2: Human Sensor Hoodie

3.3 Native Studies E-Textile Unit

The class took place over three weeks, meeting daily for about an hour. In addition to daily classroom sessions during the three-week unit, course instructors also held lunchtime sessions where students could bring their lunch and work on their projects. These sessions were not mandatory but provided an important space for students to engage in making without some of the physical and behavioral constraints of the classroom, opening up spaces for peer-to-peer mentoring and relationship building. The first week provided students with the necessary background knowledge in crafting, circuits and coding to enable them to design and make their own "human sensing" hoodies, including the sewing of simple circuits on scrap felt. Sample projects were shown to help students conceptualize their own e-textiles projects. In the second week, each student chose a design from one of ten templates based on a list we received from the classroom teacher. Designs included several forms of water (raindrops, river, snowflake), fire, wind, lightning, sun, moon, stars, and earth in the form of several locally significant mountains. Students then drew a circuitry blueprint to determine where to place the LilyPad, how to orient the LED lights, and how to create the circuitry in such a way as to minimize potential short circuits created by crossing wires. They then moved on to crafting their designs out of felt and affixing the electronic components. Because students' sewing abilities varied greatly, instructors provided instruction on an as-needed basis and focused primarily on the ways in which sewing with conductive thread differs from sewing with regular, non-conductive thread. In the third week, students turned to coding their e-textiles projects. Due to limited computer access and project completion, students learned to setup up their boards and write simple code in Modkit while working with one of the course instructors on an individual basis or in small groups of two to three students. In the third week, students also explored multiple definitions of technology, with a goal of developing counter-narratives about technology in Indigenous communities.

To give you a sense of what the boys made, we have included a table with samples of some of the boys' e-textiles projects (see Table 1). Included in the table is a circuitry diagram, completed design, and an explanation of the project's code for each featured design. With one exception, boys' designs stuck closely to the templates they were provided with, though creative license was taken with the colors of the designs and the lights. Designs ranged in complexity from having two to nine LED lights connected to the LilyPad microcontroller, with most boys choosing to connect either two (4/10) or three (4/10) lights.

Table 1: Boys' E-Textile Designs

Pedro	Sammy	Lance	Harry
			
			
If 2 conductive patches are touched, both LEDs blink simultaneously. Else, each LED blinks individually in an alternating sequence.	If 2 conductive patches are touched, 3 LEDs blink simultaneously. Else, each LED blinks individually in an alternating sequence.	If 2 conductive patches are touched, 3 LEDs stay on. Else, all 3 LEDs blink in rapid sequence.	If 2 conductive patches are touched. 3 LEDs blink in rapid sequence. Else, all 3 LEDs stay on.

3.4 Data Collection and Analysis

Daily field notes documented what happened in the class each day, focusing on what students were learning and what they were struggling with in designing and crafting with e-textiles. We also collected students' circuitry blueprints, daily photographs of students' design progress, and code screenshots. Most classroom sessions were video recorded (depending on the permission of the classroom teacher and students) and then logged, meaning that the actions seen in the video were reduced to a minute-by-minute written log of classroom activities. Sections of interest were returned to and fully transcribed as a later stage of analysis. Six students also participated in final reflective interviews, which were video recorded and lasted around twenty minutes. Topics included where students saw connections between the cultural content of Native Studies and the e-textiles unit, what aspects of their projects they were most proud of, what aspects of their projects were the most challenging, and how other individuals (family and friends) responded to their projects. Interviews were then transcribed.

We used a multi-faceted identity lens [23, 52] to understand how the heritage craft element of e-textiles might be leveraged to attract boys from non-dominant backgrounds to learn computing and to address the identity gap. Analysis of boys' e-textiles artifacts and field notes allowed us to better understand their practices and participation in the classroom community. A portfolio was created for each student that combined his initial circuitry blueprint, photographs of his in-process and completed project, and any available iterations of the code for his project. Field notes and interview transcripts were initially coded using a two-step open coding process [10] allowing themes to emerge from the data and then be refined. Salient codes included the gendered nature of craft and boys' uncertainty about participating in craft practices, design agency, and the importance of a culturally-connected assignment. This analysis of field notes helped us to better understand boys' practices during the Native Studies e-textiles unit and analysis of interviews allowed us to better understand boys' perspectives on learning computing through e-textiles activities. Because the codes that emerged from the open coding closely mirrored Brennan and Resnick's [6] conceptualization of computational frameworks, we chose to draw upon their framework because of its familiarity to a larger computing audience.

4. FINDINGS

Like other youth we have worked with in many different contexts, the American Indian boys whose experiences and perspectives are the focus of this paper initially had vague or non-existent ideas about what computing involved. Over the course of the e-textiles unit, however, we saw students' perspectives on computing change as they realized that computing could be used as a medium for self-expression and creativity, as a way to connect with others, and as a way of critically engaging in the world by asking questions of technology and using technology to ask questions. Each of the case studies that follows highlights one of the computational perspectives outlined by Brennan and Resnick [6] as they played out in an e-textiles unit within a gender segregated Native Studies class.

4.1 Computational Perspectives: *Expressing*

Though a member of the community, Sammy had previously attended a non-reservation public school and was new to Eagle High School. When the e-textiles unit began, Sammy was nervous about crafting, especially using the iron (FN, 9/24/13, p.5). He had some previous experience doing beadwork in his Native Arts class at school but reported that, "it's not the same" (int., 10/22/13, p.8). Sammy also returned to school after learning about the project and reported that his mom had said sewing was for ladies. When asked what he thought in response, he replied, "I think it doesn't matter" (FN, 9/19/13, p.2). Indeed, Sammy would later reflect that "the threading" was one of the most challenging aspects of the project.

Judging by the pace at which he worked and his dedication to the project, Sammy embraced the hybrid dimensions of the project. While he initially wanted to work on a design based on one of the community's sacred mountains, another student beat him to it and Sammy instead chose to create an e-textile design around lightning "because I wanted to be like Shazam or Captain Marvel, Captain Marvel from DC Comics" (int., 10/22/13, p.5). As Sammy delved into the crafting process, he continued to add elements to the project that married his initial attraction to the design because of a particular superhero with the cultural context of the assignment and the Native Studies class more broadly. The lightning design Sammy received only had one lightning bolt, to which Sammy decided to add a gray-blue thunder cloud, after very carefully considering the available colors (FN, 9/24/13, p.5). Initially, the addition of the cloud was meant to illustrate an important relationship in the natural world (lightning and thunder clouds "just go together," in Sammy's words), but also to cover up the LilyPad so it wouldn't be visible or, as Sammy put it, "the LilyPad wasn't going to just sit there on the sweatshirt" (int., 10/22/13, p.6). As his design evolved, however, Sammy decided to sew lights along the length of the lightning bolt and use the cloud as an anchor for his LilyPad because it made the sewing easier. Sammy asked questions at every step of the project as to avoid mistakes, so he managed to sew a functional project with relative ease.

When it came time to program his project, Sammy was very clear about the aesthetic he wanted to achieve through programming his lightning bolt. During an extended classroom session, Sammy sat with one of the instructors (Searle) and another student who was waiting to program his project at the back of the room:

> *Instructor: Okay, so, what do you want it to do when your patches are touched?*
>
> Sammy: I want, because, you know, you know how lightning, it goes chung, chung, chung [uses hands to show how lightning flashes once and then spreads out across the sky].
>
> *Instructor: Okay, that's what I thought.*
>
> Sammy: You know, how lightning flashes once together and then flashes twice.
>
> *Instructor: [using right hand to demonstrate a blinking pattern] Okay, so, you want them all to blink together once or you want it to be, like, really quick down the line? So, it's like, ch-chung [uses right hand to demonstrate lightning spreading out].*
>
> Sammy: [Repeats motion with his own hand, seemingly testing it out for fit] Yeah. Or...
>
> *Instructor: Let's try that.*
>
> Sammy: And see how it looks (video log, 10/04/13, p. 2).

Working together, Sammy and the instructor created two different programming scenarios for the lights to flash, one in which all three lights flashed at once and another where they flashed one at a time. For Sammy, like many other novice e-textile designers, there was an added degree of personalization to be found in altering the delay function, which controls how long lights stay on and off, creating a blinking or flashing effect. As the proposed codes got closer to Sammy's desired aesthetic, he started exclaiming, "Oh! That's cool! Yeah, that's how I want them all to go," and repeatedly touched the cuffs of his sweatshirt together to see the desired effect play out with subtle changes. Ultimately, Sammy preferred having all of the lights flash at once, with one added flourish. He added an extra long delay after the lights flashed to emphasize the idea of lightning striking. Then he decided to use the other code that had been developed, with each light blinking individually in rapid sequence, to meet the second condition of his project, when the conductive fabric patches were not touching. In his experiences making an e-textile project and programming it, Sammy found a new venue for creativity and self-expression at school while also being challenged academically. Asked to reflect on what he had learned at the end of the unit, Sammy replied, "Negative and positive stuff. You know, electronic stuff. The good stuff" (int., 10/22/13, p.5). Through this process, Sammy not only learned key computational concepts and practices but also developed a sense of computing as something that can be used for personal expression. Indeed, the idea of using one's e-textiles project as a means of personal expression was a theme in all of the interviews we conducted, with each boy choosing to highlight particular aspects of his identity through the design he chose to make, the colors used, and how the lights blinked when the patches were and were not touched.

4.2 Computational Perspectives: *Connecting*

Harry was a quiet but thoughtful student who participated in one of the e-textiles pilot projects but initially struggled with sewing and circuitry concepts. For his Native Studies project, Harry chose to make a fire design because of multiple personal connections. Fire reminded him of "sitting by a fire or camping" (int., 11/18/13, p.3) and also helping his grandmother to cook outside, a practice still observed by many community elders. Harry decided to craft his design out of multiple colors of felt because "that's how I really see flames, like, red, yellow, orange, dark red. That's what I think of flames" (int., 11/18/13, p.2). For Harry, this design phase of the project was especially important. Not only was he interested in creating a realistic representation of fire, the process also provided another way to connect with his grandmother. In a final reflective interview, Harry reported that his grandmother "always sews," making handkerchiefs, quilts, and shirts for sale. He reported that he often helped her with the designs and enjoyed this aspect of the project. Asked what his grandmother would think of his completed project, Harry replied sheepishly, "She's probably gonna say you can help me now with sewing. I'd just rather do the designs, but I'll help her sometimes" (int., 11/18/13, p.7).

It was probably the opportunity to strengthen his connection with his grandmother, combined with a desire to wear a light up hoodie when attending the Phoenix Light Zoo event with one of his classmates and his young nephew, that propelled Harry through a design process filled with moments of what we might term "productive failure" [35]. When it came to the circuitry for his project, Harry's initial circuitry blueprint showed three lights located about midway up the flame, all connected to a single port on the LilyPad, meaning that they all would have been programmed together. Harry also envisioned the LilyPad and lights being sewn into the back of the design so that the lights could glow through the felt. Because Harry often continued to work through questions rather than asking for help, his circuitry design process was iterative, involving lots of resewing and debugging as the design evolved through a trial and error process. Ultimately, after receiving some sewing help from one of the instructors, Harry ended up with a completed fire e-textile artifact with three LEDs, each wired to its own port. He programmed it so that, when the patches on his hoodie were touched, they blinked in rapid sequence and, when the patches were not touched, the lights stayed on. Asked about how his completed e-textile artifact connected to other things he had been learning in Native Studies, Harry explained, "[My hoodie] kind of does the same thing. Like, stories, they're always connected to something else, so that's how

I know" (int., 11/18/13, p.8). In other words, his human sensor hoodie, which could be linked with other hoodies made by his classmates, provided a computational perspective of connecting with others, much like community stories connected members to one another and to their surroundings.

Like Harry, other boys we interviewed emphasized two ways in which computation allowed them to connect with others. First, the cultural significance of their designs created a point of connection with other community members, especially around conceptions of time as cyclical and the significance of water. As Brian said about his e-textile design, "I chose a river because it flows like energy and whatever's around it can feed off of it and grow" (int., 11/18/13, p.2). Second, students saw points of connection to their immediate family members, with their light up hoodies serving as a marker of academic accomplishment and a source of pride.

4.3 Computational Perspectives: *Questioning*

Jason entered the e-textiles assignment with some trepidation even though his mom was an avid crafter and Jason had watched her sew traditional dresses for his sister and use a glue gun to create holiday decorations. Initially, Jason was concerned that he would be unable to finish his project, saying things like, "I never thought I could do this" or "I didn't think I'd get this far" (Int., 10/18/13, p.5). However, with concentrated help from one of the instructors during a study hall period, Jason was able to make significant progress on his design, a white crescent moon with two red LEDs sewn into it (see figure 3). Jason then programmed his moon, deciding on a blinking pattern where the top and bottom LEDs blinked in rapid succession when the conductive fabric patches were touched and otherwise stayed lit (see figure 4).

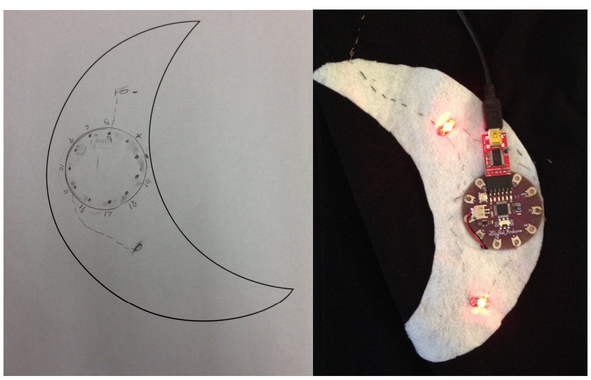


Figure 3: Jason's circuitry blueprint showing the placement of two LEDs and his LilyPad within a moon design and his completed design.

Later, asked to reflect back on the process of making, Jason emphasized his own power to make decisions about and with technology. For instance, he said, "I got excited because we get [sic] to design our own lights and, like, go on the computer and [choose] what speed we liked and I thought that was pretty cool. Honest" (Interview, 2/3/14, p.3). While Jason brought a sense of excitement and empowerment to the conversation when he talked about being able to program the lights in his project to blink, he still hesitated when asked if his project was a Native technology. He replied, "Not really because native technology is, well, we didn't really have technology. I would say ours would be like art, it would be like our technology, and how to tell time and stuff so, yeah, I don't know" (int., 10/21/13, p.9). What's remarkable about this statement is that Jason's examples are actually powerful examples of technologies, period. But dominant discourses of Western science have created a master narrative about what is and what isn't a technology. As a result, we view Jason's experiences with learning to take a questioning stance towards technology as an important first step that requires further practice and exploration.

By the end of the e-textiles unit, most students could recognize that their e-textiles projects functioned like the circuit boards inside their phones, but they had also developed a more critical stance towards technology. In some cases, students embraced their e-textiles projects as examples of "Native technologies" because they had largely designed the projects themselves. In other cases, students persisted in locating Indigenous technologies in the past and electronic technologies in the present and future. Rather than view these students' experiences as deficient or anti-technological in any way, we wish to use their experiences with questioning technology to highlight the persistence of colonial narratives and the importance of projects like this one in helping students to think about alternative narratives where their own and their communities' experiences 'count' as technological.

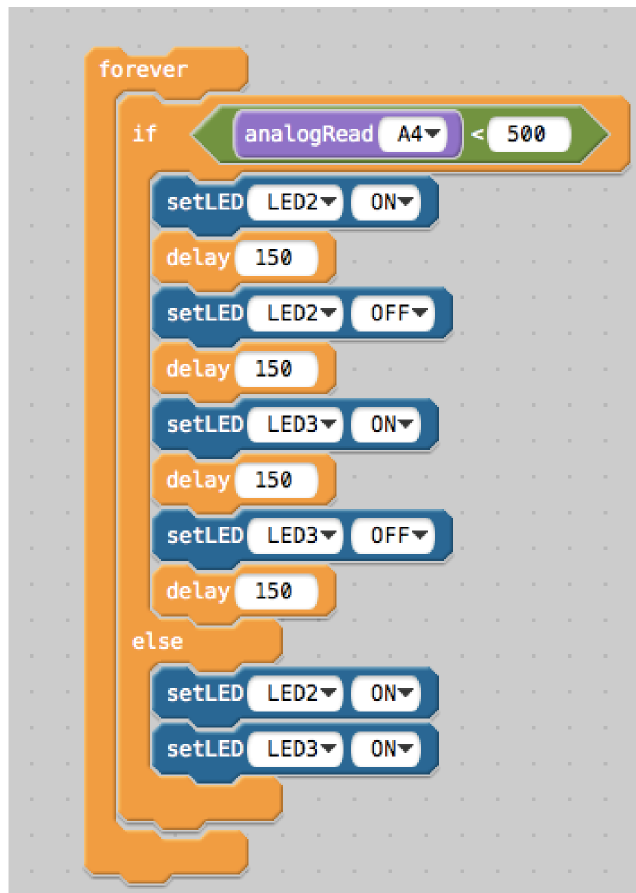


Figure 4: Code for Jason's completed project showing rapid blinking when patches are touched.

5. DISCUSSION

Although there is certainly evidence of American Indian boys learning of computational concepts and practices in our findings, we have chosen to focus more on their developing computational perspectives. Understanding how boys from non-dominant communities think about and connect with computing activities is an important step towards lessening the participation and identity gaps in computing, especially in the space of e-textiles research, which has primarily examined girls' connections to computing. What did it mean for boys to engage with e-textiles materials? How did connections to culture and community come into play? What does it mean for the design of culturally-responsive computing activities?

5.1. Challenges to Gender in Crafting and Computing

The hybrid nature of e-textiles materials [9, 25] has the potential to both reify and challenge existing gendered and cultural norms around who can engage in craft practices and who can engage in computing [1, 31]. We found examples of both in our data, though, as our findings highlight, the culturally responsive aspect of the assignment rapidly pushed boys beyond thinking about craft, circuitry, and computing as gendered and helped them to instead think about how to employ them as tools in service of the particular message they wanted to convey through their designs. Although some boys had initial preconceptions about craft as "women's work," they were also nervous about engaging in craft practices because the skills required were new and often challenging. Of the six boys we interviewed, four of them reported that sewing was the most challenging part of the project. However, as Sammy's experiences with making and programming his lightning bolt e-textile project illustrated, the hybrid nature of e-textiles materials ultimately facilitated boys' engagement with computation as a space for personal expression. Rather than merely working with code on a screen, boys were able to see their code enacted in a tangible way as the lights on their project lit up, such as when Sammy carefully tested multiple codes to achieve the desired effect of lightning flashing.

5.2. Reflections on Computation and Community Connections

In addition to viewing e-textiles materials as tools to be used in the service of expressing themselves computationally, boys also leveraged the hybrid and culturally-connected nature of their e-textiles artifacts to connect with others through e-textiles. For instance, our findings show how Harry's connection to his grandmother and her sewing practices not only strengthened his engagement in the assignment but also reinforced familial ties. In other work [42], we have shown how the tangibility of e-textiles artifacts allowed them to serve as boundary objects [50], which facilitated students' abilities to make connections through computation. More than just extending beyond the screen, students' e-textiles artifacts extended across home and school spaces. Though the boys who we focused on here didn't often tell us about seeking advice from others, we do know that finished projects were often shown off in the lunchroom at school and worn to other classes. Harry's English teacher reported that he had worn his fire-themed design to English class, where they happened to be reading one of the books from *The Hunger Games* trilogy. As researchers think about developing introductory computing activities to engage students from non-dominant backgrounds, we believe that having an artifact-based, tangible element that connects to community practices and can travel across spaces where computers may not be found is key.

Our findings also highlight boys' developing abilities to question with and through computation. While this may seem irrelevant to many computer science educators, we view critique and questioning of our taken-for-granted understandings of technology as an important element of addressing the "identity gap" for American Indian youth and others from non-dominant racial and ethnic backgrounds. Technologies in Indigenous communities have often been defined exclusively by Western science and have been used for colonization [12]. We sought to push back against these dominant narratives by engaging students in thinking about their community's long history of adapting useful technologies and also by exploring some of the ways in which Indigenous communities throughout the world are reclaiming technologies in the service of linguistic and cultural revitalization efforts [2, 26]. However, as Jason's experiences with deciding whether to call his e-textiles project an Indigenous technology or not highlight, narratives about technology as defined by Western science are incredibly powerful and will take repeated efforts to develop strong counter-narratives in which American Indian students (and others from non-dominant communities) recognize the rich technological histories of their own communities.

5.3 Considerations for Culturally-Relevant Computing

Though most computer science educators will likely encounter few American Indian students in their careers, we want to suggest that our work has implications for why we might want to develop computational perspectives amongst a wide range of student populations in the United States and beyond and provides one pathway for doing so through the incorporation of novel, hybrid materials and heritage craft practices. As more and more youth worldwide experience computing not just in schools but also in after school clubs and community makerspaces [38], it is important that educators not only engage the variety of perspectives, experiences, and cultural backgrounds that students bring with them but also recognize that computing must make a contribution back to the community to be valued, whether through developing language learning software or encouraging youth to take up heritage cultural practices. In addition, computing education needs to explicitly address legacies of colonization, racism, and gender disparities. While we drew upon community stories around the elements in crafting the computing activity described here, there is a wide range of heritage and vernacular cultural practices that educators might take up, depending on the student population and the comfort level of community partners.

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7. REFERENCES

[1] Aal, K., von Rekpwski, T., Yerousis, G., Wulf, V., & Weibert, A. (2015). Bridging (gender-rleated) barriers: A comparative study of intercultural computer clubs. *Proceedings of Gender and Information Technology (Gender IT)*. Philadelphia, PA: USA: ACM.

[2] Bang, M., Marin, A., Faber, L., & Suzokovich, E., III. (2013). Repatriating Indigenous technologies is an urban Indian community. *Urban Education, 48*(5), 705-733.

[3] Baretto, F. & Benitti, V. 2012. Exploring the educational potential of robotics in schools: A systematic review. *Computers & Education, 58*, 978–988.

[4] Biju, S.M. (2013). Taking advantage of Alice to teach programming concepts. *E-Learning and Digital Media, 10*(1), 22-29.

[5] Brayboy, B.M.J. & Maughan, E. (2009). Indigenous knowledges and the story of the bean. *Harvard Educational Review, 79*(1), 1-21.

[6] Brennan, K. & Resnick, M. 2012, April. New frameworks for studying and assessing the development of computational thinking. Paper presented at the annual meeting of the American Educational Research Association, Vancouver, BC, Canada.

[7] Buechley, L. & Hill, B. (2010). LilyPad in the Wild: How hardware's long tail issupporting new engineering and design communities. *Proceedings of Designing Interactive systems (DIS)* (pp. 199-207). Aarhus: Denmark: ACM.

[8] Buechley, L. & Eisenberg, M. (2008). The LilyPad Arduino: Toward wearable engineering for everyone. *IEEE Pervasive Computing*, *7*(2), 12-15.

[9] Buechley, L. & Perner-Wilson, H. (2012). Crafting technology: Reimagining the processes, materials, and cultures of electronics. *ACM Transactions on Computer-Human Interaction, 19*(3), 21:1-21:21.

[10] Charmaz, C. (2000). Grounded theory: objectivist and constructivist methods. In N.K. Denzin and Y.S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 509-535). Thousand Oaks, CA: Sage.

[11] Cohoon, J., & Aspray, W. (Eds.). (2006). *Women and information technology*. Cambridge, MA: Massachusetts Institute of Technology Press.

[12] Deloria, V., Deloria, B., Foehner, K., & Scinta, S. (1999). *Spirit & Reason: The Vine Deloria, Jr., Reader*. Fulcrum Publishing.

[13] Dewhurst, M., Keawe, L., MacDowell, M., Okada-Carlson, C.N.K., & Wong, A.K. (2013). Ka ulana 'ana i ka piko (In weaving you begin at the center): Perspectives from a culturally specific approach to arts education. *Harvard Educational Review, 83*(1), 136-146.

[14] Dimond, J. & Guzdial, M. 2008. More than paradoxes to Offer: Exploring motivations to attract women to computing. Georgia Institute of Technology Technical Report. Retrieved on August 27, 2012 from: http://gacomputes.cc.gatech.edu/Members/jpdimond/dimond Paradoxes.pdf

[15] DiSalvo, B. & Bruckman, A. (2011). From interests to values: Computer science is not that difficult but wanting to learn it is. *Communications of the ACM 54,* 8, 27-29.

[16] DiSalvo, B., Guzdial, M., Bruckman, A., & McKlin, T. (2014). Saving face while geeking out: Video game testing as a justification for learning computer science. *Journal of the Learning Sciences, 23*(3), 272-315.

[17] Dyson, L.E., Hendriks, M., & Grant, S. (Eds.). (2007). *Information technology and indigenous people*. Hershey, PA: Information Science Publishing.

[18] Eglash, R. & Bennett, A. (2009). Teaching with hidden capital: Agency in children's explorations of cornrow hairstyles. *Children, Youth, and Environments, 19*(1), 58-73.

[19] Eglash, R., Bennett, A., O'Donnell, C., Jennings, S., & Cintorino, M. (2006). Culturally situated design tools: Ethnocomputing from field site to classroom. *American Anthropologist, 108*(2), 347-362.

[20] Eglash, R., Gilbert, J., & Foster, E. (2013). Broadening participation: Toward culturally responsive computing education. *Communications of the ACM, 56*(7), 33-36.

[21] Eglash, R., Gilbert, J., Taylor, V., & Geier, S.R. (2013). Culturally responsive computing in two urban, after-school contexts: Two approaches. *Urban Education, 48*(5), 629-656.

[22] Ensmenger, N. (2010). *The computer boys take over.* Cambridge, MA: Massachusetts Institute of Technology Press.

[23] Fields, D. & Enyedy, N. (2013). Picking up the mantle of "expert": Assigned roles, assertion of identity, and peer recognition within a programming class. *Mind, Culture, and Activity, 20*(2), 113-131.

[24] Forte, A. & Guzdial, M. 2004. Motivation and nonmajors in computer science: Identifying discrete audiences from introductory courses. *IEEE Transactions on Education,* 48 (2), 248-253.

[25] Golsteijn, C., van den Hoven, E., Frolich, D., & Sellen, A. (2014). Hybrid crafting: Towards an integrated practice of crafting with physical and digital components. *Personal and Ubiquitous Computing, (18)*, 593-611.

[26] Hermes, M., Bang, M. and Marin, A. (2012). Designing Indigenous Language Revitalization. *Harvard Educational Review, 82*(3), 381-402.

[27] Hill, S.H. (1997). *Weaving new worlds: Southeastern Cherokee women and their basketry*. Chapel Hill: University of North Carolina Press.

[28] Hull, G. A., Kenney, N. L., Marple, S., & Forsman-Schneider, A. (2006, Spring). Many versions of masculine: An exploration of boys' identity formation through digital storytelling in an afterschool program. *Afterschool Matters, 6,* 1–42.

[29] Jacobs, J. & Zoran, A. (2015). Hybrid practices in the Kalahari: Design collaboration through digital tools and hunter-gatherer craft. *Proceedings of CHI 2015* (pp. 619-628). Seoul, Republic of Korea: ACM.

[30] Kafai, Y. B., & Burke, W. Q. (2014). *Connected code*. Cambridge, MA: Massachusetts Institute of Technology Press.

[31] Kafai, Y. B. Fields, D. A., & Searle, K. A. (2014). Electronic textiles as disruptive designs in schools: Supporting and challenging maker activities for learning. *Harvard Educational Review*, 84*(4)*, 532-556.

[32] Kafai, Y., Lee, E., Searle, K., Kaplan, E., Fields, D., & Lui, D. (2014). A Crafts-Oriented Approach to Computing in High School: Introducing Computational Concepts,

Practices, and Perspectives with Electronic Textiles. *ACM Transactions on Computing Education, 14*(1), 1-20.

[33] Kafai, Y.B. & Peppler, K.A. (2011). Youth, technology, and DIY: Developing participatory competencies in creative media production. *Review of Research in Education, 35*, 89-119.

[34] Kafai, Y.B., Searle, K.A., Martinez, C., & Brayboy, B. (2014). Ethnocomputing with Electronic Textiles: Culturally Responsive Open Design to Broaden Participation in Computing in American Indian Youth and Communities. *SIGCSE '14: Proceedings of the 45th SIGCSE technical symposium on computer science education* (pp. 241-246). Atlanta, GA: Association of Computing Machinery.

[35] Kapur, M. (2014). Comparing learning from productive failure and vicarious failure. *The Journal of the Learning Sciences*, *23*(4), 651-677.

[36] Kelleher, C., Pausch, R., and Kiesler, S. (2007). Storytelling Alice Motivates Middle School Girls to Learn Computer Programming. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (pp. 1455-1464). San Jose, CA.

[37] Keene, A. (2015, Feb. 4). Nike gets it right; Brand collaborates with O'odham designer. *Indian Country Today*. Retrieved on April 19, 2015 from: http://indiancountrytodaymedianetwork.com/2015/02/04/keene-nike-gets-it-right-brand-collaborates-oodham-designer-159028

[38] Kulkarni, Y.R. (2013). Small ideas, big opportunities: FabLab at Vigyan Ahram Oabal, India. In, Walter-Hermann, J. & Büching, C. (Eds.), *FabLab: Of machines, makers and inventors* (pp. 231-237). Bielefeld: Transcript Verlag.

[39] Lameman, B.A., Lewis, J.E., & Fragnito, S. (2010). Skins 1.0: A curriculum for designing games with First Nations youth. In *Proceedings of FuturePlay 2010* (pp. 105-112). Vancouver BC: ACM.

[40] Margolis, J. & Fisher, A. 2002. *Unlocking the clubhouse*. Cambridge, MA: The MIT Press.

[41] Margolis, J.. Estella, R., Goode, J., Holme, J., & Nao, K. 2008. *Stuck in the shallow end: Education, race, and computing.* Cambridge, MA: MIT Press.

[42] Meerbaum-Salant, O., Armoni, M., &Ben-Ari, M. (2010). Learning computer science concepts with Scratch. *Proceedings of ICER 2010* (pp. 69-76). Aarhus, Denmark: ACM.

[43] Millner, A. & Baafi, E. (2011). Modkit: Blending and extending approachable platforms for creating computer programs and interactive objects. In *Proceedings of the 10th International Conference on Interaction Design and Children* (*IDC '11*) (pp. 250-253). ACM: Ann Arbor, MI.

[44] Nakamura, L. (2014). Indigenous circuits: Navajo women and the racialization of early electronics manufacture. *American Quartery, 66*(4), 919-941.

[45] Nasir, N.S. (2012). *Racialized Identites*. Stanford, CA: Stanford University Press.

[46] National Science Foundation (2014). Science and Engineering Indicators 2014. Retrieved on February 19, 2015 from http://www.nsf.gov/statistics/seind14/content/etc/nsb1401.pdf.

[47] Oldenziel, R. (1999). Making technology masculine: Men, women, and modern machines in America. Amsterdam: Amsterdam University Press.

[48] Parker, R. (1986/2011). *The subversive stitch*. New York: I. B. Tauris.

[49] Porter, L., Guzdial, M., McDowell, C., & Simon, B. (2013). Success in introductory programming: What works? *Communications of the ACM, 56*(8), 34-36.

[50] Searle, K.A. & Kafai, Y.B. (2015). Culturally responsive making with American Indian girls: Bridging the identity gap in crafting and computing with electronic textiles. To appear in *Proceedings of Gender IT*.

[51] Star, S.L. & Griessemer, J.R. (1989). Institutional ecology, 'translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science, 19*(3), 387-420.

[52] Tan, E., Calabrese-Barton, A., Kang, H., & O'Neill, T. (2013). Desiring a career in STEM-related fields: How middle school girls articulate and negotiate identities-in-practice in science. *Journal of Research in Science Teaching, 50*(10), 1143-1179.

[53] Wing, J. (2006). Computational thinking. *Communications of the ACM,* 49, 33-35.

[54] Wolber, D., Abelson, H., Spertus, E. & Looney, L. 2011. *App Inventor: Create your own Android apps.* Sebastopol, CA: O'Reilly Media, Inc.

[55] Yardi, S. & Bruckman, A. 2007. What is computing? Bridging the gap between teenagers' perceptions and graduate students' experiences. *Proceedings of the 3rd International Workshop on Computing Education Research* (pp. 39-50), Atlanta, GA.