Ethnocomputing with Electronic Textiles: Culturally Responsive Open Design to Broaden Participation in Computing in American Indian Youth and Communities

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ABSTRACT

There have been many efforts to increase access and participation of indigenous communities in computer science education using ethnocomputing. In this paper, we extend culturally responsive computing by using electronic textiles that leverage traditional crafting and sewing practices to help students learn about engineering and computing as they also engage with local indigenous knowledges. Electronic textiles include sewable microcontrollers that can be connected to sensors and actuators by stitching circuits with conductive thread. We present findings from a junior high Native Arts class and an academically-oriented summer camp in which Native American youth ages 12-15 years created individual and collective e-textile designs using the LilyPad Arduino. In our discussion we address how a culturally responsive open design approach to ethnocomputing with e-textile activities can provide a productive but also challenging context for design agency and cultural connections for American Indian youth, and how these findings can inform the design of a broader range of introductory computational activities for all.

Categories and Subject Descriptors

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

General Terms

Human Factors

Keywords

Electronic textiles, education, Indigenous Communities, K-12

1. INTRODUCTION

Though recent observations suggest that computer science is making a comeback [20], participation in computer science and entry into technology-related careers by underrepresented groups continues to be alarmingly low (NSF, 2009). The situation has been particularly dismal for American Indian youth and communities [i]. Efforts in broadening access to and participation of indigenous communities in computer science education over the last two decades have not left any discernible impact. Explanations for this persistent trend point to a combination of factors, such as lack of access to advanced computer science courses and curricula [18], lack of teacher preparation [12], and lack of culturally responsive ways to work with underrepresented groups [10]—all factors which have also impeded the progress of computer science education at large. In order to better understand the critical connection between culture and computing for engaging indigenous students, we focus on approaches that have been developed in ethnocomputing.

Ethnocomputing recognizes local systems of computational knowledge at multiple levels, including data structures, algorithms, tools and theory, and uses [27]. One approach, called culturally responsive computing, has focused on designing tools and environments that help students learn about computation and its cultural relevance [9]. In culturally responsive computing, local practices of ethnocomputing are leveraged to create Situated Design Tools (CSDTs) in which interactive computational models make explicit the deep-seated mathematical and computational principles already present in the cultural practices of particular groups. Eglash and his colleagues have developed a Virtual Bead Loom tool that allows students to virtually create beaded designs following algorithms present in Shoshone-Bannock beadwork that are guided by the principles of recursion and iteration [7]. In a different vein, Lameman and her colleagues [17] developed a game design curriculum for First Nations youth in Canada that taught students the fundamentals of game design while encouraging them to draw upon their own cultural experiences. The goal of culturally responsive computing, with few exceptions that have focused on both computation and cultural knowledge, has been primarily for students to learn about computation.

In this paper, we propose an approach to ethnocomputing that combines the teaching of computation and aspects of local culture[ii]. We do so by introducing electronic textiles (hereafter, e-textiles), which connect crafting practices such as sewing and decorative beading that have a long history in many indigenous communities to computing and engineering practices [3]. E-textiles include sewable microcontrollers that can be connected to sensors and actuators by stitching circuits with conductive thread to create wearable, interactive clothing, home furnishings, and soft toys [4]. By using e-textiles to help students learn about engineering and computing, Native arts and crafts can be connected with electronic computation. In this context, we can promote the 'design agency' of computer science learners in culturally responsive ways [8] by constructing software or

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physical artifacts that facilitate the translation of their ideas into a technical realization—an idea very much in line with efforts to promote computational thinking [29]. As of yet, little attention has been paid to how cultural viewpoints situate engagement with computational thinking.

The focus of this paper is to examine, conceptually and empirically, how an ethnocomputing approach to learning with e-textiles can engage K-12 youth in formal and informal educational contexts in design agency, the processes through which individuals grapple with the constraints and possibilities of specific design tools to create artifacts and connect to cultural practices and concepts [8]. We present findings from two projects, a 10-week unit in a Native arts class and a 2-week intensive summer camp. Within these projects, 39 Native American youth created either individual or collective e-textile designs using the LilyPad Arduino e-textile construction kit. In the discussion we address how and in what ways e-textile activities provide a context for design agency and cultural connections, and how these findings can inform the design of introductory computational activities that broaden access for all.

2. BACKGROUND

Like the rest of US students, few American Indian/Alaska Natives ever venture into computer science [28]. While American Indians comprise 0.9% of the U.S. Population (2010 U.S. Census), they only received 0.4% of all bachelor's degrees, 0.2% of all master's degrees, and 0.1% of all doctorates awarded in computer science, computer engineering and information in 2012. In full numbers, this translates to American Indian/Alaska Natives having received 57 bachelor's degrees, 20 master's degrees, and 2 doctorates in computing-related fields in 2012 [30]. These statistics clearly indicate that current programs and efforts in schools are not meeting the needs of indigenous students and communities.

One key reason has been the lack of access [13]. While there are and have been efforts to increase the number of American Indians/Alaska Natives in STEM-related fields, most are targeted at undergraduate and graduate students. Several short-term summer experience programs, like the Native Explorers program (www.nativeexplorers.org) for high school students at Oklahoma State are the exception to the rule. These summer programs expose Indigenous students to STEM, some through culturally responsive pedagogies, but they are short-term and, therefore, unlikely to foster the kind of broad, systemic change that is needed. Moreover, the vast majority of these efforts target the few students who have both completed high school and maintained an interest in STEM. Thus they do not address the heart of the issue—the disconnections between indigenous conceptions of computing knowledge and approaches to teaching STEM content in schools.

Most ethnocomputing initiatives have employed approaches that are culturally responsive in nature, meaning that they value student knowledge, recognize differing knowledge systems, and prioritize community or local relationships [7, 26]. Culturally responsive computing is explicit about the complex computational and mathematical thinking present in local knowledge systems, so that students, through design activities, come to see computational thinking as part of their culture heritage. The virtual bead loom [7] and the game design curriculum [17] described in the introduction are illustrations of how these cultural connections to computing can be realized.

In our approach to ethnocomputing, we wanted to use culturally responsive computing not just as a context for situating computation (i.e., to make it relevant to existing cultural practices) but also as a context for challenging beliefs about computation (i.e., what is computing). By design, e-textiles integrate indigenous technologies of crafting and sewing with electronic technologies and computer programming [3] and thus provide a context for examining both connections and disconnects. On one side, practices such as basket weaving, beading, and pottery making have historically been a part of many American Indian cultures, with local (indigenous) knowledge about these practices being passed down from generation to generation [14]. Using electronic textiles thus links computational practices to traditional practices that were historically (and in many cases, remain) an integral part of community life, and can illustrate how people are connected to one another and their surrounding environment—relationships that are considered critical in Indigenous Knowledge Systems [1, 2, 16].

E-textiles are a relatively new addition to a long line of construction kits that merge the tangible with the virtual side of computing. There are few established academic canons to which students have to respond; instead, in the DIY tradition, most of the e-textiles community operates in informal settings, developing new applications and conventions. This feature makes e-textiles an especially promising context for broadening Indigenous communities' participation in computer science.

In making e-textiles, there is thus the opportunity for students to learn crafting physical artifacts, sewing circuits, and programming functionalities and, in the process, developing design fluency that facilitates the translation of their ideas and identities into a technical realization. This development of design agency is meant, "to encompass not only what we make but who is making it; at the same time we design things, they are designing us" [7, p.69]. Design agency thus connects to computational thinking [29] but adds a cultural dimension. Viewing computational thinking through the lens of design agency can take into account not only the constraints of digital tools but also the constraints imposed by a legacy of colonization. American Indian peoples, especially elders, often view electronic technology as yet another alienating vehicle of colonization—one that is responsible for making their youth English-language dominant and making them more interested in watching television than in listening to stories that have been passed down through the generations [5, 16]. In our two studies with American Indian youth and communities, we examined how students developed design agency in making e-textiles artifacts and how this was connected (or not) to community funds of knowledge and students' identities as American Indian youth.

3. E-TEXTILES IN CLASS AND CAMP

Our research on Ethno E-textiles (hereafter, e2textiles) takes place in an American Indian community outside of Phoenix, Arizona. The community is comprised of two tribes that have historically been allies and has roughly 10,000 enrolled members. One of the tribes is known for its pottery and the other for its basket making. When we initially developed our partnership with the community, we envisioned drawing upon these practices to engage students in computing activities. Since then, we have gone through an iterative process of co-designing with community partners and refining a series of e2textiles workshops focused on promoting design agency through the linkage of community funds of knowledge, including local indigenous knowledges (e.g., knowledge about beading, knowledge of plants), with computing and craft practices [11].

We began our research in March 2013 with 12 seventh and eighth grade students (3 males, 9 females) enrolled in a Native Arts class at a charter school located in the community. Working with an experienced American Indian art and mathematics teacher who we will call Ms. Kilgore, we co-designed a 10-week e2textiles unit to supplement the Native Arts curriculum. Based on findings from this workshop, we then designed a two-week e2textiles unit for a summer camp, this time with a more explicit focus on community funds of knowledge by designing a collaborative quilt project around local flora. 27 junior high students (9 male, 18 female), including 5 students from the Native Arts class, enrolled in the camp located at a community college on tribal lands. In both cases, students programmed their e-textile projects using the Modkit visual programming environment [21], which is designed as an overlay to the Arduino programming language. Through analysis of field notes and video logs of classroom sessions documenting students' emergent artistic and computational design processes, interview transcripts in which students reflected on their understandings of the relationships between e-textiles and community funds of knowledge, and artifacts themselves, we identified how students developed design agency in crafting and computing, and connected (or not) to their notions of their culture while making e-textile artifacts. We also examined the choices we, as instructors, made that promoted or hindered students' design agency.

E-Textile Class

The 10-week e-textile unit in the junior high Native Arts class was our first attempt at integrating community funds of knowledge and computing. Working together with Ms. Kilgore, we made a conscious decision to give students very few design constraints, since this was how Ms. Kilgore had approached all of the other projects students engaged in throughout the year. Students were told that they had to design and program an e-textile project with at least two LEDs (light emitting diodes) and a LilyPad Arduino. We showed examples of projects that we had made and that students had made in previous e-textiles workshops, but we did not give students any design constraints in terms of what they could or could not make. As a result, students mainly created felt patches with e-textile elements that could later be affixed to their hoodies or backpacks (see Figure 1).

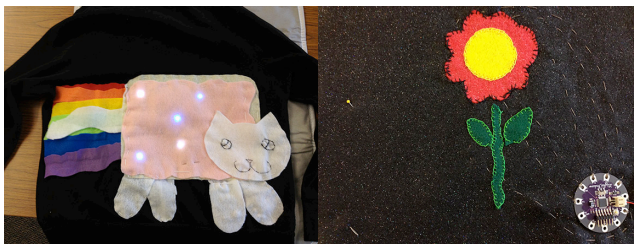

Figure 1: Student-designed e-textiles from the Native Arts class with a Nyan Cat (left) and a flower (right).

The e-textile designs highlighted personal interests in youth media culture—favorite bands, anime characters, and YouTube videos. These designs were both similar and different from other items, mainly beaded bracelets and necklaces that students made in the Native Arts class. Ms. Kilgore told us that students' first attempt at creating something in a given medium often had a non-traditional design, such as a beaded Hello Kitty bracelet where the art form was a Native craft, but the design was from popular culture. Once students developed a sense of the medium, they often made second and third projects with more traditional designs, according to Ms. Kilgore.

In the case of the e-textiles unit, most students only made one e-textile project and even the small number of students who made two e-textile projects did not return to local cultural designs. Rather, they persisted with designs connected to personal interests in youth media culture and expanded their programming repertoire. For instance, seventh-grader Rachel made a heart and lightning bolt design for her first project. The lightning bolts flashed in a blinking pattern. For her second design, Rachel made a design inspired by her favorite anime show, whose logo she carried around inside the laminated cover of her binder. The e-textile project inspired by this design included two conductive fabric patches, which required more sophisticated programming skills to make the project work. Still, when we asked students to compare their experience with e-textiles to other things they had done in Native Arts, they stressed the similarity of using needle and thread and the difference of using electronic components.

While the e-textile artifacts students made were thematically similar to those made by other youth [15], the Native Arts students thoughtfully integrated craft and technology in ways not previously seen amongst novice designers. For instance, almost every single student chose to hide the LilyPad and even to cover the LEDs with felt to achieve particular types of "glowing" effects. Many students used stitches that were more advanced than the simple running stitch used by novice designers, opting instead to use blanket stitch for edging and satin stitch to cover LEDs. Students also had more extensive patterns within their programming loops, even at the simplistic level of making LEDs blink on and off. Rachel worked for several class periods to perfect the timing of the blinks for the LEDs behind her lightning bolts to make them look as if they were flashing. Some students also programmed their artifacts and then requested to change the programming several days later after showing the artifact off to peers at school and family at home. In these ways, we saw students exercising design agency. However, this sense of agency was not as connected to community funds of knowledge as we had hoped.

E-Textile Camp

Drawing upon our experiences with the Native Arts class, we worked closely with staff from the community's Cultural Resources Department and the American Indian Studies program at a local community college to design a second e2textiles workshop for an academically-oriented summer camp with 7th and 8th graders. Our goal for working with these partners was to respond to our observation that students often made e-textiles artifacts connected to popular youth culture rather than to their indigenous cultures because they had a working definition of technology, where technology was electronic technology and, therefore, located outside of community knowledges. Having shared our observations about students' views on technology with our community partners, we collectively arrived at the theme of agriculture and local plants because it allowed us to discuss how the community has used various kinds of technology throughout its history. We used a quilt in the shape of tribal lands to situate students' e-textile designs of local plants.

We began the e-textiles portion of the camp with a brief orientation to e-textiles and how to design circuits, and program sensors and actuators. Working with our community partners, we then provided students with different examples of community technologies while also drawing from local funds of knowledge. Examples were used to illustrate innovations of technology from

inside the community and adaptations of technology appropriated from outside the community in order to show students that technology is an essential part of their heritage. Students were challenged to reflect upon ways to make computation useful and meaningful to their community, and reflective of their identities as local indigenous people. After having learned about local indigenous technologies and appropriations, students worked on designing e-textile squares for the community-quilt over the course of two weeks (see Figure 2).

Figure 2: Student-designed quilt from the summer camp (left) and quilt square detail of Alex's design (right).

We asked each student to choose a plant to make into an e-textiles design from a binder containing pictures of about 20 local plants. When students chose the plant they wanted to represent, staff members from the Cultural Resources Department were present to answer students' questions about the plants and to provide them with the local indigenous names of the chosen plants. Students later designed quilt squares based on their chosen plants.

Based on prior experience, we encouraged design-agency through an iterative design process where students tested each electronic component and programmed it as they went along rather than waiting until the end to write a computer program. This kind of semi-structured design task (as opposed to the completely open-ended nature of the Native Arts class) facilitated the creation of designs that were more complex in terms of their circuitry and programming. Two students incorporated sensors, 2 students added sound, 1 student included an RGB light, and 1 student used 2 lilypads to support a system of 13 LED lights coded to blink in complex patterns. Several of the students transitioned from coding in Modkit (a graphical programming environment) to coding in Arduino (a syntactical programming environment) as the complexity of their coding developed. Another student, Alex, created a design that was the product of an iterative design process where he wrote multiple programs, incorporated sensors, a piezo speaker, and an RGB light. As he explored a broad range of hardware and software, Alex often worked additively to explore an idea and then subtractively to remove hardware in favor of previous ideas that he had already prototyped, or to simply try something new altogether. The result of this was a colorful design representing two stages of cotton growth augmented with colorful lights choreographed to a simple looping melody (see Figure 2). During the second week of production, we hung the quilt background, shaped to look like a map of tribal lands, in the classroom so that students could begin to envision their contributions as a part of their community quilt. On the final day of the workshop, students had the opportunity to temporarily affix their quilt square to the wall hanging (allowing them to take their work home after completing the workshop). Their quilt was displayed during a public reception where the students' families were invited to view their work.

4. DISCUSSION

In this paper, we proposed an approach to ethnocomputing that focused on culturally responsive open design and investigated how learning with electronic textiles about circuitry and computation in two different contexts, a class and a summer camp, situated students' understanding as members of an indigenous community. By culturally responsive open computing, we refer to practices that connect community funds of knowledge and computing in culturally relevant ways but with fewer design constraints than those imposed when students work with culturally situated design tools. We found that working with e-textiles was a productive context for students in the Native Arts class and the summer camp to develop design agency, though this occurred in different ways and with varying degrees of success depending on the context. Some examples of students exercising design agency might include: taking a photograph of a plant and abstracting it into a simpler more stylized design, designing novel solutions to connect hardware in ways that avoid short circuits, designing spatial solutions that enabled them to conceal the hardware within their designs, designing light and sound compositions that augment and animate their squares to reflect their imaginations and the nature of their subject matter, and thinking through logic to produce novel algorithms to mostly accomplish intentionality, as opposed to settling with accidental discoveries. Students also exhibited a high level of craft by executing straight and blanket stitches that were carefully sewn, as well as using applique shapes, which they carefully cut.

In the context of the Native Arts class where the design task was more open-ended, perhaps to a fault, students exercised their design agency by choosing to make projects connected to youth media culture and by focusing on honing their programming skills, such as when Rachel spent several class sessions thinking about whether or not how she had programmed her lights to blink really looked like lightning flashing. In the context of the more narrowly constructed design task in the summer camp, students pushed even further into the realms of circuitry and computation, adding sensors to their projects and learning how to program them. However, we noticed in informal debriefing interviews that students had forgotten the indigenous names for the plants they had represented in their quilt squares, suggesting that in the future we can improve our efforts to ensure that students retain local knowledges and computation.

In both of our workshops, we learned that students benefitted from an increased level of design constraint, at least insofar as their knowledge of computational concepts and practices was concerned. When their designs were constrained, students moved more quickly beyond the initial design phase and were able to devote more of their time to circuitry and programming. In addition, because there were a limited number of plant designs to choose from, one of the ways in which students could distinguish their design from others was through the use of additional sensors and actuators and through more complex programming. However, the more constrained design task did not necessarily lead to students to make more connections between community funds of knowledge and computing. This may have been because the workshop was still structured in such a way that about one-third of the time was focused on making cultural connections and the other two-thirds of the time was focused on crafting and programming the e-textiles artifacts themselves. One challenge going forward in working with more open-ended design tasks will be not only to find the right balance between local indigenous knowledge and computation in our workshops but also to integrate the kind of explicit connection between culture and

computation made in Eglash and colleagues' CSDTs. One potentially productive avenue may be to explore the incorporation of some of the elements that have recently been identified as successful in introductory programming courses at the college level, such as having students program in pairs and having student-led instruction [24].

Our findings present an interesting conundrum that is a challenge at large for ethnocomputing. While culturally responsive design tools situate computation within an explicit, narrowly-defined cultural context, culturally responsive open design like the e2textiles workshops described in this paper situate computation within a broader cultural context. This has the potential to give the learner more agency about what he or she learns, but it also runs the risk that students will continue to view community funds of knowledge, such as local indigenous knowledges, and digital computation as distinct bodies of knowledge that do not and should not connect with one another. Ironically, the Cultural Resources Department, community college, and junior high staff members we worked with had far more expansive views of technology than the youth we worked with. This suggests that e-textiles and other more open-ended design tools without specific disciplinary connections in formal schooling are needed to develop a supportive space for youth to explore and work out their own identities and stances on technology. Further research and connections between researchers and community members are needed to determine the appropriate balance between community funds of knowledge and computation, as well as the appropriate level of constraints in these kinds of open-ended design tasks.

From Eglash and his colleagues' work, we learned that whether or not a computing task is culturally responsive matters more than whether or not the learner is situated within the culture of the design tool [8, 9]. In other words, a Latino student can learn as much about computation from engaging with a CSDT built around cornrows as an African American student can learn. However, we would argue that this approach fails to recognize that learning about culture in and of itself, particularly as it relates to students' identity development within their culture and place, is an equally important outcome—one where we suspect that context does matter.

There are some special considerations in the case of American Indians that need further exploration in future research, especially when we consider connecting craft knowledge to computing. Craft, like many other types of Indigenous knowledge, is rooted in particular places and connected to activities that extend beyond the space of a classroom and a computer screen. For instance, when we think about integrating community basket weaving practices with e-textiles materials, we know that there are certain times of the year during which reeds for making baskets can be collected. We also know that particular designs have cosmological significance, ties to origin stories, and are expressed within local aesthetic frameworks. Knowledges of these designs is not something that can be learned by anyone, but something that the learner must be prepared to know, coming to understand the responsibility that comes with such knowledge and the protocols for appropriate use. What might it look like to more fully engage cultural contexts in culturally responsive computing for Native American youth and communities? Would such an approach more fully engage participants and facilitate relationship building amongst participants and between participants and instructors [19, 22]? Would such an approach help students connect digital media to local indigenous technologies in ways that encouraged its appropriation and culturally responsive adaptive re-use? All these are questions for further research.

At the same time, we recognize that there are lessons from our research that contribute to the broader framework of culturally responsive computing and the goal of broadening participation in computing for all students. Echoing the work of other researchers interested in broadening participation in computing [19, 25], our implementation of two workshop models, one more open-ended and one more-constrained in terms of the design task and the cultural context, highlights the importance of providing a variety of different contexts in which youth can explore computing [19]. As such, it is important not only that we continue to develop culturally-specific models tied to heritage with a balance of design constraints and space for design agency to happen, but also that we create open-ended yet focused design tasks for those students with other interests, such as the students in our first workshop who primarily expressed interest in youth popular culture. We must remind ourselves that culture is not static; its dynamic nature allows that the integration of electronic technology and popular culture need not necessarily be at odds with the culture of one's ancestors. Indeed, culture isn't something that is fixed in the past; it is constantly in flux, the notion of culture is an approximation, and it is being made on a daily basis.

Through the work with our community partners, and American Indian youth, we learned that providing all students with design agency to imagine forms of computation responsive to their interests and identities has the potential to provide embodied learning experiences that allow students to see themselves as successful stakeholders of the digital age. Contextualizing computer science learning within local funds of knowledge and practices may provide students with the ability to tie what they are learning to the history and emergence of their respective communities in ways that can meaningfully broaden participation in computing. By broadening participation in computing we not are not only referring to the promotion of diversity in computing, but we also refer to the importance of cultivating learning scenarios designed to support diverse expressions of computing reflected by broader perspectives.

[i] Throughout this paper, we use American Indian, Alaska Native, American Indian/Alaska Native, Native or Native American, and Indigenous interchangeably. We are aware of the wide range and variation among the 500 tribal nation groups in United States.

[ii] By culture, we mean a shared way of thinking, engaging, and viewing the world by a group of people. Culture is often rooted in place, language, and ways of being, doing, learning, and thinking about things that are unique to a particular group. Our notion of culture is that it is fluid and not concrete, meaning that perceptions of culture, to certain degrees, vary among community members. Our understandings of culture in this project are driven by how our community partners define their own culture, and cultural pedagogy for their youth.

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