Cultural-Centric Computational Embroidery

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ABSTRACT

Many computer science education efforts promise liberation and equality, but that promise often goes unfulfilled. Teaching computation through E-textiles has been one way to achieve this promise because it has increased student engagement and enabled identity work. Although some approaches to teaching CS through E-textiles have been demonstrated as effective, there is not yet work using a programmable electronic embroidery machine (computational embroidery), or work that makes culture itself a topic of learning. In a six-week summer school course, we explored this opportunity, teaching a culture-centric embroidery class that combined hand embroidery and computational embroidery. Students incorporated their identities into their projects by using a block-based coding language to create embroidered patterns. They enthusiastically engaged with the programming aspects of the course and sought to make complicated and beautiful work that interwove their diverse cultures and identities. This paper offers insights into what it is like to teach computing with a cultural lens. Our curriculum and pedagogy offer instructors a template to incorporate these technologies and topics into their courses.

CCS CONCEPTS

• **Applied computing → Education**.

KEYWORDS

broadening participation, K-12, secondary, e-textiles

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1 INTRODUCTION

Efforts to broaden participation in computing at the K-12 level have led to an increasing number of schools (53%) offering CS, however, participation is low. Code.org reports that 6% of high school, 3.9% of middle school, and 7.3% of primary school students are enrolled [4]. Furthermore, historically marginalized populations are also underrepresented in K-12 CS [4, 9]. Prior work suggests that there are systemic barriers like sexism, racism, and classism that lead to inequities in primary and secondary computing education [9].

To address issues of access, representation, and inequity, researchers and practitioners have turned to Culturally Relevant Pedagogy (CRP), which emphasizes the importance of including students' cultural references in all aspects of learning[3, 5, 17]. Gloria Ladson-Billings' CRP emphasizes student academic success, fostering positive ethnic and social identities through cultural competence, and nurturing students' critical consciousness to challenge societal inequalities [12]. Furthermore, Geneva Gay emphasized the importance of mutual respect between cultures in the classroom and the critical need to recognize the contributions and perspectives of different ethnicities to foster a more inclusive and dynamic learning environment [7].

One way researchers and practitioners have utilized CRP in the classroom is through electronic textiles. Electronic textiles or e-textiles refer to the computational bridge between electronic components like LEDs, sensors, and actuators with fabric (i.e. Arduino Lilypad) [1, 2]. This connection provides an opportunity to integrate computer science and making through programming the electronic components. The emphasis on textiles also allows for rich engagement with culture. For example, prior work includes engagement with Native American and Indigenous cultures and exploring the nuances of embroidery as a typically gendered activity [11, 18].

Prior work has excelled at exploring identity and culture through physical computing on fabric. However, prior work often focuses on particular cultures (e.g. [18, 19]) and programming electronic components which are then later integrated into textiles. In this paper, we instead center *embroidery* and culture themselves as subjects of learning, framing computing as an enabling tool. There are traditions of embroidery from cultures around the globe that have been part of dress, ceremony, and day-to-day life; these traditions often include elements like repeating patterns and shapes which can be translated into programming concepts like loops, variables, and functions. *Computational embroidery* involves using a

programmable embroidery machine to express these repeating patterns through automation. These connections between computing, embroidery, and culture suggest many possibilities for integrating CRP into computing education.

To explore these possibilities, we designed and taught a co-constructed 6-week high school course. In this class, students learned how to hand-embroider, the traditions of embroidery in their cultures, and how to program a programmable embroidery machine to create patterns of personal meaning.

2 RELATED WORK

Electronic embroidery machines have been used in a variety of formal and informal settings. Some designers have worked out ways to playfully use an electronic embroidery machine by creating an educational embroidery game where the machine and the user play back and forth drawing and making bodies [13]. Others have offered conference workshops to use embroidery machines to turn images into swatches to make patches. This workflow requires computation but does not require coding [16]. A few workshops have integrated programming with embroidery. A workshop at Fablearn showcased a Catrobat app that allows users to code designs for embroidery [20]. Additionally, at ACM Conferences on Human Factors in Computing (CHI) and the SIGCSE Technical Symposium on CS Education (SIGCSE) there have been workshops on Turtlestitch, a block-based embroidery program built on Snap!. [21–23]. This work has thus far been with adults and not in schools.

Using similar materials but different technologies and techniques, primary and secondary formal and informal settings teach e-textiles in efforts to broaden participation in computing. An embedded e-textile 8-week computer science curriculum with 272 students in a variety of formal school settings using Lilypads, Arduinos, and Light Emitting Diodes (LEDs). Kafai et al. found that students viewed e-textiles as computation and their perceptions of CS broadened, erasing gender differences in perceptions of CS [10]. Another study utilized live-action role-playing (LARPing) and E-textiles to interested middle school girls [6]. This project used microbits and wearables to create costumes and engage in role-playing. Moreover, A 2019 meta-analysis of e-textiles called for the development of more complex e-textile activities so that the medium of teaching is not limiting student capacity to learn, stating that it is important to draw on students' funds of knowledge, or life experiences outside the classroom [8]. It also called for a more holistic assessment, capturing more than just the technical learning.

To further efforts to broaden participation, some researchers and practitioners have adopted culturally-responsive work with e-textiles; however, there are many challenges and limitations. One is the complexity of identity work: in 2015 a study on culturally responsive making with indigenous youth found that identity work with youth is complicated often because of external narratives about who can do science and who defines culture [18, 19]. This leaves the question: *Do these same findings apply when using computational embroidery?*

One limitation is the cost of materials for making and embroidery in the classroom. Some researchers are working to lower the cost of the electronic components. The LilyTiny is a sewable affordable ($6) microcontroller that allows students to control LEDs [14]. Another limitation is teacher support. Often these techniques, technologies, and materials can also be new to teachers. It's important to ensure teachers are supported so they feel confident teaching CS [15]. A study using the electronic textile unit within Exploring Computer Science realized how important it was for teachers to engage with and understand the technology and the associated pedagogical content knowledge [8]. Overall, identity work and critical making is complex work that requires teachers and students to stretch their knowledge bases, trust each other, and take intellectual risks.

3 CONTEXT

In this section, we describe the context for our course, which we called TECHstyles, to communicate that we would be exploring textiles and technology.

3.1 Program

We taught the course as a part of an Upward Bound Program. Upward Bound (UB) is a federally funded program that provides college readiness, summer school, and extracurricular opportunities to low-income and/or first-generation students (those who would be the first to attend college in their families). UB partners with colleges and universities in the US to host and manage these programs for the population in the schools' region. This year, our local UB program served approximately 125 students and was located at a large public university on the west coast. The UB program is free to students and provides lunch and a stipend for students who participate. UB staff recruits students by visiting their schools before they apply. Accepted students may then choose to enroll.

3.2 Instructors

Because prior work has shown the importance of teacher engagement in CS learning [8, 15], we share our experiences and attitudes about both embroidery and computing below (with names anonymized as animals).

Instructor Giraffe has spent their entire life marveling at textiles from their African heritage. Although they had never embroidered before teaching this class, the combination of computing, art, and culture was exciting. Instructor Giraffe is a second-year PhD student with experience teaching computing in school and extra-curricular environments. They are deeply motivated by equity and justice and are devoted to making CS a more welcoming environment for all students.

Instructor Octopus has been embroidering since before she could write, regularly using textile arts as a form of self-expression. She also has fifteen years of experience teaching middle and high school math and science courses and has worked in a school to build and embed a maker space broadly into the school's curriculum. Her introduction to computing was horrific university CS classes and later she had much better experiences advising extra-curricular science and robotics clubs. Part of her teaching work allowed her to embed CS into geometry and statistics courses.

Instructor Salmon has had little prior experience with hand embroidery, dabbling in it after discovering his mom's box of textiles and a life-long admiration for his family's strong culture of Mexican embroidery. The prospect of teaching students computing in an exploratory and identity-driven way was intriguing. Salmon

is an undergraduate sophomore and has experience teaching middle school students Earth Science after school and, more recently, TAing in an introductory programming college course. He wishes to connect underrepresented groups to the technology that has brought most so much while seemingly forgetting about so many by improving what is fundamentally important—like education.

3.3 Students

Students self-reported demographic data (see Table 1) in a survey during the first weeks of the course. Survey responses were all optional and open-ended. Students also chose their own pseudonyms. The class had twelve students who all selected this course as one of their top choices. Of the twelve students, ten assented to share their experiences and work as part of this study. Of the ten who are part of this work, one student had to leave the class and missed the final two weeks. This class had diverse genders and ethnicities, and all students were adolescents who took this course as an elective.

3.4 Tools

Hand embroidery, The craft of hand embroidery is inherently algorithmic. It is an image composed of many tiny stitches. These tiny stitches often repeat thousands of times in a single image. One way of thinking of each stitch is as a pixel, which on its own does not tell a story, but together makes a picture. Thread color, stitch type, and stitch location form a larger whole of the embroidered piece (See the first image in Figure 1). We chose to use hand embroidery as an introduction to this course and a medium to provide familiarity with the context for computational embroidery.

Turtlestitch[1]. This platform offered a simple block and browser-based editor built on SNAP[2]. The platform enabled students to design images that were then automatically converted to machine code to print on an electronic embroidery machine. Designs are made by placing blocks that command a small turtle to move, leaving behind a trail of stitches. students also have control over stitch type and color. Furthermore, blocks are organized into different color-coded sections like motion, sensing, and control. Blocks simplified the coding experience, employing a basic and memorable nomenclature. For example, what would be called a *for loop* in a text-based programming language like Java, is renamed to *repeat* in Turtlestitch. This software also offers a relatively seamless way of sharing designs. Students can publish their projects, allowing other students to save and edit them. Turtlestitch also allowed students to create their own functions and variables, facilitating more learning and creating about abstraction.

Embroidery Machine. We used the Brother SE600, which was selected for its affordability and ease of use. At the time of this course, it cost about $400.

3.5 Curriculum

We had several guiding principles in our course design. First, we decided that the course would be *co-constructed* both in content and assignments. When we co-constructed assignments, we would elicit ideas for what the week would entail and how students wanted to be assessed. Students would proffer suggestions and we would guide discussion until we had class consensus on the goals and requirements for the assignment. Our second guiding principle was that we would make space for students to explore and express themselves as they wanted. The rationale for co-construction and exploration was to create an environment where students felt empowered to focus on pursuing things they were curious about, and not focus on or worry about grades. Third, we would work hard to make sure we were not asking questions with right or wrong answers because we wanted to emphasize that there was more than one way to do anything and that one way was not more correct than another.

The **first week** of the class we explored hand embroidery. On day one we introduced ourselves and immediately gave students access to the supply cart. We asked them to pick up a piece of fabric, a needle, a pair of scissors, and thread before we demonstrated how to thread a needle and tie a knot. We then helped them make their first stitches. We shared resources that included hand embroidery tutorials and a stitch dictionary with hundreds of stitch types and instructions. Later in the week, after students felt comfortable with their embroidery supplies, we co-constructed an assignment for week one, soliciting ideas and feedback for the week's requirements. The conversation resulted in an assignment where they demonstrated three new stitches, uploaded a picture of their work and reflect on the questions: *What was challenging? What did you learn? What are you proud of?* We graded the assignments for completion and hosted a 'gallery walk' where students displayed their work– and peers and instructors walked around and provided feedback on a piece of paper.

For the **second week** of the course, we explored cultural traditions of embroidery. During week one, instructors asked students if there were cultural traditions they were curious about exploring, and students shared several like Mexican Embroidery traditions, Arab embroidery on Abayas, and Japanese cultural embroidery traditions. We visited the library to research the cultural traditions of embroidery. There, the librarian explained how to use the library search engines, and how to request books, and pulled several books based on student requests. After some individual student research, she took us on a tour of the library that ended in the cultural textile section. The next day we co-constructed the week's assignment which students decided should be a mood board that was full of things that were inspiring their next project. This mood board needed to include at least one picture, and at least one external link, and answers to the reflection questions: *What did you learn? What are you still curious about? What are you excited to do next?*

The **third week** introduced the basics of writing Turtlestitch code. We started day one with a short tutorial that made an embroidered robot. On paper, we had students read and explain what the code was doing. We also demonstrated how the machine works. Students modified, shared, and embroidered their robots. On the second day of the week, students had a short tutorial on how to create functions. Instructors were careful to reiterate proper terminology like loops and variables because most students intuitively understood how the loops worked, but did not have the language to talk about them. The week's co-constructed assignment required students to use create a computationally embroidered work. Students decided that this assignment should require that they make at least one shape, create a function, use some aspect of repetition,

[1]Turtlestitch.org
[2]https://snap.berkeley.edu/

Pseudonym	Age/Grade Level	Gender Identity	Race/Ethnicity	First Gen	Other Identities
Eric	17, 11th grade	He/Him	Asian Vietnamese	yes	
Ricky Bobby	15, 11th grade	Male	Hispanic/Latino	yes	
Red	15, 10th grade	Girl or Female	Hispanic and Latina	yes	
Babo	16, 11th grade	Male	Hispanic/Latino	yes	
Bob	10th grade	Male	American Mexican	no	
Jasmine Green Milk Tea (JGMT)	16, 11th grade		Asian Vietnamese	no	another language at home
The First Ever Queen (FEQ)	15, 10th grade	She/Her	Black	yes	
Mimi	16, 11th grade	Female	African/Somali	no	
Jellyfish	16, 11th grade	Female	Chinese Immigrant	yes	Immigrant
Chocolate Milk	17, 12th grade	Male	Asian Chinese	yes	

Table 1: Students self-selected pseudonyms and self-reported demographics of age, gender identity, race/ethnicity, first-generation college student status, and any other identities they wanted researchers to know. Students could opt out of any question.

and either learn how to change color or learn how to change the stitch.

The **fourth week** began with co-constructing the weekly assignment. Students chose to continue honing their skills in Turtlestitch by using more complex code, so we designed an assignment where students had to use functions, loops, and variables to create a work inspired by the cultural embroidery they explored at the library. Students spent class time brainstorming what their assignment would look like and we challenged them to identify what elements of their embroidery would use the required programming elements. For example, a student who created traditional Aztec patterns stated that he would "Definitely multiple loops because it has lots of repeating patterns and I want to see if I can learn to use the sensing blocks on Turtlestitch." Students spent the next day tracing code which used variables, functions, and loops to create a sun. They were able to ask instructors questions about the program and how to best use functions, loops, and variables in their own assignments. The last day of the week was a work day for their assignments, and because students wanted more time we moved this week's reflection assignment to next week.

Week five began the week with a discussion about the reflection for week four and students decided on reflection questions for the week. They also shared a group reflection that they'd like more time learning variables. Students reflected and wrapped up their week four assignment. Students started brainstorming their ideas for their final project and continued printing and fine-tuning their designs on the embroidery machine. The final project due at the end of week 6 only had two requirements– the first was to make whatever you wanted, and the second was that some components needed to use Turtlestitch. Additionally, students would be showing off their final project at a program-wide final-day gallery walk. Instructors met one-on-one to discuss each student's final project ideas. The goal of these meetings was to make sure students had goals for the final project. Additionally, because no assignments had strict deadlines we checked in with each student about any outstanding work to make sure they had the support they needed.

During **sixth week** students continued to work diligently on their final projects. Students would often be waiting outside of class before it began and several students would stay after to work until the instructors needed to leave. Because each student was working on something different, this week required a lot of individual support. A few students were exploring ways to incorporate LEDs into their projects and others were exploring the potential to incorporate speakers or small servo-motors to make different embroidered parts move. On the last day of this week, we worked with students to create one final reflection which included these questions:

- What was your experience with hand embroidering and using Turtlestitch? Feel free to discuss the similarities and differences of each method.
- What is your favorite part of your final project?
- What was your favorite part of this course?
- How have you grown as a computer programmer/coder?
- If you had more time what would you change or want to explore more in class?

Instructors also captured a picture of each student with their final project. The summer school culminated in a banquet where students and classes from across the program demonstrated their work. The course had a dedicated table where all the final projects in their various stages of completion were displayed. Students proudly showed off their work to the broader community of peers, instructors, and family members.

4 REFLECTION

Because this is not a research paper, we did not gather data intended for rigorous analysis to answer a research question. Instead, we captured student work and reflected upon it systematically. All instructors for this course met and discussed each of our student's work and the experiences we had with those students. Then we selected three students who had work that represented the work of the class. This section presents these three students, sharing their chosen pseudonyms, and their work. We then share our experiences and reflections on our students' work.

4.1 Student 1: The First Ever Queen (FEQ)

The first week of class, as we were all getting to know one another, the students were slow to volunteer to chat. Over the course of the week, FEQ tried a few different hand embroidery stitches before she picked bright orange thread and started making the complicated orange pattern seen in Figure 1. At the end of the last class that week she pulled Instructor Octopus over and exclaimed, *"Usually I have to wait for other people to tell me 'You did that!' but today I get to say, 'I did that!'"* As educators, we found her enthusiasm encouraging. In the second week, after we visited the library, FEQ mentioned in passing that her hand embroidery was inspired by the practice of henna, a tradition where women paint their hands with complex patterns (see Figure 1). She had organically incorporated elements from her culture into her work. It was even more exciting to us that she was so proud of her work. We noted with interest that FEQ did not include any references to henna in her mood board, it seemed that her identity was so entangled, she assumed it was understood. One of the beginning of class warm-ups in the first week was to design a class mascot. FEQ designed a robot that was waving a sign saying TECHstyles, which was the name of the course. When engaging with Turtlestitch, FEQ worked independently and made many different remixes of robots.

For her final project, FEQ wanted to make a robot that moved. She had never used electronics before but had always wanted to. Because this course was co-constructed and projects were open-ended, FEQ was able to select something that interested her. In meeting with an instructor, FEQ was surprised at the freedom in the final project. At first she seemed nervous and very hesitant about her ability to make so many choices and the responsibility they would entail. After she made some sketches and some plans, she got started. While she was working on the robot she used a class-communication system to check in with Instructor Octopus and wrote, *For my Robot I'm working on my Turtlestitch part I'm hoping to get that part done by the end of today ... I GOT THIS!!! I hope so lol but I will send you a progress picture once I finish the Turtlestitch part.* Her final project was an embroidered robot that was comprised of several different programmed embroidery works that she planned out, cut up, and recombined so that the robot could be connected to a servo motor and wave hello (see Figure 1). FEQ wove themes of her identity into each of her projects over the course of the term. However, we noticed that she did not always choose to weave cultural identity into her work. She chose other things she was curious about and that she wanted to pursue.

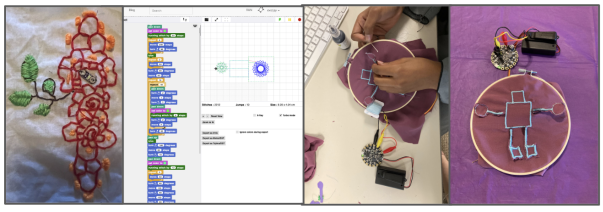

Figure 1: FEQ's work from left to right: FEQ's henna-inspired hand embroidery, FEQ's code in Turtlestitch, FEQ working on her final project, FEQ's final robot that waves for the end of program demonstration

4.2 Student 2: Red

Throughout the course, we noticed that scaffolding was necessary to help Red learn. She always had a clear sense of what she wanted to create but needed help translating her ideas into actionable steps in Turtlestitch. During Week 3, Red wanted to make a cup of bubble tea, as it was her favorite drink. Once she created the rectangular cup, she asked Instructor Giraffe for help. Although we had gone over how to create loops and she understood that she needed to create loops to represent the boba pearls, she struggled with the semantics. Thus Instructor Giraffe sat with her as they mapped out each step of creating the loop for the boba pearls. First, she learned to create a circle and how to change the diameter of the circle. Then she created a loop of 10 consecutive circles; however, the circles exited the boundaries of the rectangle. Next, she divided the boba into multiple layers by using variables for position and creating a second loop. With each step, she showed more confidence and independence. By the time she finished the bubble tea cup and boba, the week had ended; however, Red wanted to continue her project. Red's journey throughout Week 3 showed us the value of scaffolding in teaching. Her journey from conceptualizing a bubble tea design to executing it in Turtlestitch demonstrated the critical role that structured, step-by-step guidance can play in a student's learning.

During Week 4 she added to her project, by writing the word "BOBA" at the top of the cup. This time, she did it all on her own. Ultimately, she decided to keep adding to her boba work for her final project. She created a turtle to reside inside the boba (see Figure 2). Not only did she create this independently, but she was so proud of the work she did. She smiled from ear to ear as the watched her completed project printing on the embroidery machine and shared it with pride at the family showcase at the end of the course. As the weeks progressed, Red's growing confidence and increasing independence in her work were evident. This progression underscores the significance of providing continuous support to students until they feel equipped to tackle challenges independently.

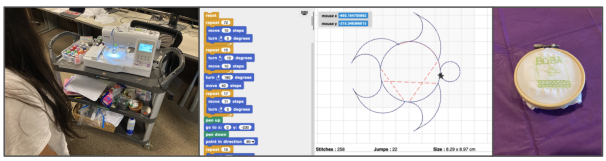

Figure 2: Red's work from left to right: Red using the embroidery machine, Red's code to create a turtle in the middle of her Boba cup, Red's work which she shared at the final demonstration.

4.3 Student 3: Ricky Bobby

Ricky Bobby always worked hard and integrated his Mexican culture into his work. You would see his blank fabric at the beginning of class and walk by towards the end of class to a masterpiece. He began the course by hand-embroidering Mexican flowers around his favorite football team's logo. During Week 3 he recreated a Mexican flower in Turtlestitch. Like FEQ, integrating his identity into

his work was an intrinsic action that happened before instructors introduced elements of culture into the class.

During Week 4, he programmed a traditional Aztec pattern. Instructors often saw him creating lines and triangles through trial and error and on the last day of the week, it all came together to create a beautiful pattern. He learned that using loops and variables would help keep the size of his lines and triangles consistent. Additionally, a thicker stitch would make the pattern stick out. Ricky Bobby's iterative approach, particularly evident in his creation of the Aztec pattern, highlighted that trial and error can be a powerful learning method for students. His experimentation with loops and variables, as well as his exploration of stitch thickness, underlined the importance of self-directed exploration in mastering concepts.

Ricky Bobby seldom asked for assistance and would always integrate his culture with passion and pride. For his final project, he decided to create a patch to go on one of his baseball caps with his name and a traditional Mexican flower silhouette surrounding it. After spending a few days programming, he was one of the first to print on the embroidery machine. He then moved on to hand embroidering the flowers. During the final family showcase, he continuously brought over family and friends to see all of the work that he did throughout the summer. Ricky Bobby's desire to showcase his work to family and friends during the family showcase emphasizes the value of community recognition in the learning process. We learned that students engage more with their work when they're connected to it.

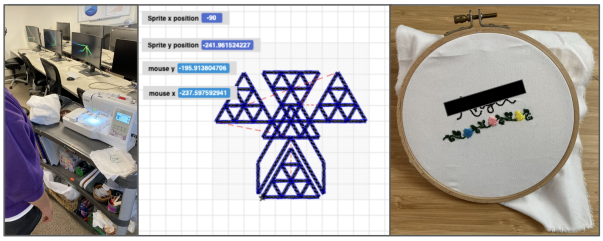

Figure 3: Ricky Bobby's work from left to right: Ricky Bobby running the embroidery machine, The middle image is the code for an Aztec pattern, Ricky Bobby's final work inspired by Mexican floral embroidery traditions.

4.4 Themes

When reflecting on these and other students' work from this course, we observed several themes.

Identity. Students incorporated their identities and interests into the work they did. FEQ tied in henna and later robots, both without any prompting from instructors. Red incorporated her love of boba and turtles into her final work. Ricky Bobby incorporated his sports teams and his cultural heritage. All of the students incorporated their interests, identities, and curiosities into the work. They were excited about and proud of the work they created. Each day, they would come into class and begin working on hand embroidery or their code without any prompting.

Iteration. There were several challenges in teaching this course. The first was building student confidence with the machine, which was in contrast with their enthusiasm and willingness to take risks when doing hand embroidery. Several expressed fear that they would break the machine. We believe this means that students delayed in their first computational embroidered work, and therefore had less time to iterate and refine their code and its physical manifestations.

Collaboration. Due to the layout of the classroom, which was a computer lab, students were in rows facing away from each other. Because students did not have other classes together they did not know each other before this course. We often started class with an ice-breaker warm-up question. Students were slow to collaborate with each other. When instructed, students shared feedback and worked in groups, but until the end of the course, most students work independently.

Future Plans. This course was only six weeks so students expressed a desire to keep working after the course wrapped up. FEQ started researching ways to acquire her own sewing machine to continue exploring embroidery and computer science. Many students were excited to showcase partially completed works on the final day of the course. One student pulled Instructor Octopus aside to show her a technique that allowed him to make a fluffy texture– he asked if he would be able to keep his work so as to incorporate that texture. Many students shared plans to continue their work and try new things.

5 DISCUSSION

This was a delightful class to teach. We found it rewarding to watch students explore textiles, embroidery, cultural traditions, computation, and debugging. Students engaged enthusiastically and tied their own identities into their work. This is in line with work done by Searle and Kafai which explored embroidery, culture, and identity with Native American youth [18, 19]. All students quickly engaged with hand embroidery, computation, and computational embroidery. Teaching computing from a computational embroidery context seems to be an additional textile application that has the potential to broaden participation in computing, which aligns with previous work done with e-textiles [8].

We reflected on improvements for this class if it were to run again. We would have encouraged students to "push" their code to the embroidery machine sooner and iterate more often. We would encourage more collaboration between students. We would spend more time in the exploration of culture, because we only had one day at the library, it felt a little rushed. Because of the physical components of the course, students and instructors would both be excited to spend more time embroidering.

Computational embroidery curriculum and techniques open doors for new avenues of research into computational embroidery and its educational possibilities and opportunities to better understand identity. It offers instructors new methods to engage students in learning to program.

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