Lighting up Learning: Teachers Pedagogical Approaches for Mak(e)ing Computing Culturally Responsive in Electronic Textiles Classrooms

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***Abstract*— *This paper identified and analyzed computer science educators' culturally responsive approaches to teaching an electronic textiles curricular unit in their high school classes. By examining surveys, interviews, and weekly reflections from 17 teachers, this qualitative study reports how learning about electronic textiles, and then teaching this curricular unit to students, enabled teachers to better support their learners through empathy, relationships, and a new appreciation for how students' home and cultural knowledge. We found that educators honored expertise not typically valued in computer science, brokered rich, authentic interactions with students in and outside of class, strengthened school-home connections, and uplifted students who had not felt successful in computing environments before.*

***Keywords*—** *computer science teachers, culturally responsive pedagogy, emotional scaffolding, electronic textiles*

I. Introduction

Computer science (CS) education in the United States is shrouded with deeply-held conceptions of who belongs in computing spaces, how it should be taught, and which knowledges and skills are valued. These ideologies, along with barriers to access for all but the most elite students, have led to a severe underrepresentation of women and people of Color in computing. The absence of these marginalized groups is pronounced in the technology industry, in colleges and universities, in K-12 schools, and is a primary focus of recent calls to reform these disparities and broaden the participation of diverse students in introductory CS classes.

Hands-on activities, or *constructionist* interventions, have examined around the world for their potential to deepen learning and provide more equitable instruction in computing [1]. As a learning theory, constructionism highlights how students build knowledge structures, a process that happens best through making things by hand [1]. *Electronic-textiles* (e-textiles) is a constructionist medium that can provide authentic and inclusive programming experiences [2], and involves constructing circuits in common household materials like fabric and paper to create "soft" artifacts like clothing, accessories, and stuffed animals to be programmed with the aid of sewable computers [3]. Scholars argue that e-textiles projects can encourage students to think computationally, to design, tinker, and build artifacts using a variety of unconventional, low-cost, open-source tools, resulting in personally meaningful, uniquely and individually handcrafted artifacts that can be taken home and incorporated into students' daily lives [3].

However, we believe that new curricula alone cannot sufficiently transform the inequitable dynamics of CS in society and in schools. Computing educators must also embody a culturally responsive orientation that disrupts dominant and prevailing discourses when introducing CS to diverse introductory students. Culturally responsive pedagogy (CRP)[i] is an asset-based teaching philosophy that centers the unique strengths of historically marginalized students, build community within the classroom, improve academic outcomes, and bolster students' sense of wellbeing and belonging in the world [4, 5].

Learning activities that celebrate and bring student designs to life can alter inequitable structures for groups that continue to be deeply underrepresented in CS [6]. While both constructionism and CRP have been found to be transformative and liberating for students in computing classes, how CS educators' pedagogical approaches are informed by their own learning about particular curricula has been less studied.

This paper examined how the complex and multi-layered process of learning unfolds for educators, through teachers' perceptions and reflections on their culturally responsive approaches to teaching e-textiles activities in their computer science classrooms. The study involved 17 high school teachers who learned about then implemented a new e-textiles curricular unit in their introductory computer science classrooms. Data were collected before and during the professional development (PD) sessions as teachers participated in constructionist activities as learners, and also through reflection interviews after classroom implementation was completed.

II. Background

A. Culturally Responsive Pedagogy

Critical scholars have urged computing educators to explicitly adopt a culturally responsive teaching mindset, which would help to contextualize CS content for diverse student audiences [2]. Often the term *culture* is ascribed to people belonging to a common nation-state, an ethnic or religious group, but here and in education literature, culture is recognized as fluid,

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heterogenous, multi-dimensional, and goes beyond the static histories, customs, and traditions of essentialized groups [4]. An example of this amalgamation of culture: a student is a second-generation Mexican-American girl, a millennial, an agnostic who enjoys hip-hop culture. CS teachers with extensive cultural knowledges of the communities they serve, must therefore hold a broader space for individual student identities and the distinct assets that they each bring to the classroom, then build on those in their teaching. Thus, CRP can be described as a teacher orientation or philosophy, rather than a method or strategy that can be easily adopted. CRP-aligned educators iteratively consider and reflect on pedagogy along these themes [5]:

- Conceptions of knowledge held by CRP teachers;
- Conceptions of self and others held by CRP teachers;
- Social relations structured by CRP teachers

Some curricula have developed in the nexus of CRP approaches and computing, resulting in learning activities intentionally designed to shift the conceptions of knowledge and the computational artifacts typically valued in CS. Prior CRP-informed constructionist lessons centered ethnic or vernacular artifacts, practices, narratives in computing classes and in e-textiles curricula. Analyses of student data showed that such activities engaged and uplifted marginalized groups in CS education by leveraging students' personal interests and priorities, as well as any prior knowledge of programming and computational thinking.

Pedagogues with constructionist, equity-oriented approaches must additionally strive to make cutting-edge CS content and technologies more explicit and accessible to diverse students. Effective computing teachers utilize pedagogical practices that are most appropriate for their unique school contexts and established classroom norms. This includes holding high academic expectations of all students, skillfully scaffolding academic instruction, and assessing classwork in ways that build students' confidence to create and innovate [6].

CRP teachers are also called to form intentional and inclusive learning communities in the classroom. In computing education literature, scholars have examined how educators how they broker a peer culture by encouraging sharing of digital and technological literacies, to strengthen students' connections with one another, their teachers, and their communities [4].

B. Electronic Textiles and Culturally Responsive Making

As student and community knowledge is celebrated and woven into curricula, culturally-situated technologies are employed, and educational relationships are galvanized, dominant structures within schools and computing classrooms can be altered for marginalized student groups that continue to be deeply underrepresented [7]. Emerging studies have found that e-textiles can help students learn about computing, circuitry, and crafting in public school classrooms [8]. Other critical scholars reported that e-textiles education positioned students' personhood and cultural identities as assets as personally relevant projects were designed and crafted by each student, advancing dominant computing practices [9].

However, in most prior studies of e-textiles education, classroom teachers did not deliver instruction to their students. With the exception of our initial study on the transformative impact of e-textiles on teachers' professional growth, [ii] there are have been no published studies of how educators operationalize e-textiles lessons in urban public school computing classes, where constraints are numerous and a severe lack of resources is commonplace. In these prior explorations, curriculum implementation was largely managed by the academics who authored the lessons, facilitated instruction, assisted in trouble-shooting, and/or assessed the effectiveness of their interventions. Critical scholars warn of the limitations of such research-practice partnerships, that they can re-inscribe common deficit positioning and devalue the knowledge and skills of working-class communities of Color in computing [10].

Research emphases have also been on student outcomes, namely, on documenting the academic and socioemotional gains observed among youth participating in e-textiles in their computing classes. Largely absent in prior CS education or e-textiles literature is teacher voice, how educators' conceptions of self and others shifted to incorporate culturally responsive practices to broaden participation in computing. We wondered: *What culturally responsive approaches do educators employ, when they attend PDs to first learn about then teach electronic-textiles activities in their computer science classrooms?*

III. METHODOLOGY

In this study, we focused on what CS educators learned in PD and how they were informed by students as their classrooms were transformed into makerspaces through e-textiles activities. By examining how instructors' positioning, routines, pedagogical approaches, and content knowledge came together, we hoped to understand how constructionist lessons could help welcome diverse students to computing.

A. Setting and Participants

This study took place in Los Angeles-area Exploring Computer Science (ECS) classes. ECS is a yearlong introductory high school computing course that offers students opportunities to explore, design investigations, think critically, test solutions, and solve real problems.[iii] Though the curriculum is now taught in schools nationwide, ECS students demographically represent the rich diversity of urban Los Angeles .

An innovative e-textiles unit was co-authored by researchers and classroom teachers to fit into ECS's project-based, inquiry-oriented pedagogical model and build on students' prior programming skills developed in earlier units of the ECS course [8]. The new unit was structured around four increasingly complex e-textiles projects that reinforced students' understanding of computational concepts, such as sequences, loops, conditionals, and variables, and apply them in a new context: a text-based programming language (Arduino). New programming content like nested conditionals, storing input from sensors, and functions were also introduced. The curriculum was subsequently revised with two years of pilot study and feedback from five high schools. The professional

development (PD) program that accompanied the unit was also redesigned based on feedback from teacher-participants from those first two years.

In 2017-18, the third year of the project, the program grew to include the teachers who are the subjects of this paper. This sample was selected by the ECS-school district liaison, who sent out an initial call for participation to the Los Angeles-area listserv for all teachers who had completed ECS' two-year PD program and taught ECS for multiple years. The liaison volunteered his own class and chose 16 others among those who had responded to his e-mail invitation. He aimed to maximize variety in their pedagogical styles, approaches to classroom management and culture-building, and school settings. The selected 17 teachers had between 3 to 37 years of professional classroom experience. Demographically, their collective high schools served between 72% and 99% students of Color, between 2% and 41% English learners, and 47% to 97% of their students qualified for the free/reduced meal program.

All 17 teachers consented to participate in our research, knowing that their responses to our data requests would not affect their inclusion in the e-textiles project. The educators were at liberty to interpret facilitate the lessons in their own style, and to adopt the new unit in place of either the Data or Robotics units in the existing ECS curriculum. They were directed by PD facilitators to ground the constructionist activities in students' individualized designs of personal expression and cultural relevance, though guidance in CRP approaches was not provided. In addition to the new curriculum, the 17 teachers received a modest stipend for each PD they attended, and a set of supplies and tools for implementing the e-textiles lessons in one ECS class. The project also budgeted for the teacher and student participants to keep all completed artifacts.

In early 2018, the participants engaged in four day-long Saturdays of professional development to experience the new e-textiles lessons firsthand. The PDs were planned and facilitated by the three ECS teachers who had participated in the first two years of the pilot study, with support from e-textiles experts on our research team. All of the workshops were designed to position the participants as learners, to develop their own computing content knowledge through crafting, programming, and making their own e-textiles artifacts come to life.

B. Data Sources

This inquiry was part of a larger data collection effort, which included quantitative pre-post student tests, classroom observations, student artifact analyses, etc.[3] Although instrumentation and investigator bias is inescapable in qualitative data collection, we worked as a team to construct study-specific, discovery-oriented inquiries that welcomed teachers' perspectives with open-ended questions designed to impose little or no limitations on their contributions to the study [11]. The teachers had many avenues for narrating their e-textiles journeys. They spoke to researchers about the hopes and apprehensions they held before volunteering for the pilot study, they responded to the experience of participating as learners in the PDs, during the school year as they taught e-textiles, and also after they finished teaching the unit. For this paper, the following were analyzed for teachers' expressions of CRP themes:

- Initial interviews before the PD series (n=17);
- Survey evaluations after each PD (4 x 17 teachers = 68);
- Weekly reflective logs during classroom implementation (13 x 17 teachers = 221)
- Final interviews post-implementation (n=17).

The interview protocols, surveys, and log prompts were drafted jointly by the larger research team and were administered online by the first author. Interview were audio-recorded then transcribed. The survey questions were adapted from post-PD surveys utilized by the ECS program to solicit feedback on their PD workshops. They were conducted online, took less than ten minutes to complete, and participants were given time to do so at the end of each PD. The reflective log entries were completed by each teacher before the end of the week on a Google Form during the pilot implementation. With this format, we encouraged the teachers to respond from their own frame of reference and share their feelings freely, at different time points and through various media.

D. Analysis

We used a general inductive approach for data analysis [12], to code these pre-, mid-, and post-implementation data for observations along the three CRP categories previously outlined by Ladson-Billings [5]. The first author developed a spreadsheet of the initial coding frame [12], which was discussed and revised with the second author. The codes were then organized into broad themes to address our research question. This rigorous, systematic, and iterative process enabled us to analyze data excerpts along several themes that were identified by our participants, to bring forth only themes that were common across all data collection points.

IV. FINDINGS

The e-textiles lessons catalyzed cognitive, cultural, and emotional shifts around learning for CS teachers, and we report only findings echoed across participants that spoke to the emergence of the three CRP themes. The most illustrative quotes are featured in the interest of brevity. Double quotation marks (") denote direct quotes and single quotation marks denote denaturalized and condensed excerpts. All names are pseudonyms.

A. Conceptions of Knowledge: Everyone has Expertise

The teachers all noted that they had volunteered to teach e-textiles because they anticipated e-textiles would be attractive to students underrepresented in CS settings. The educators told us they aimed to facilitate classes on a dynamic, leveled playing field where learners of all prior experiences were welcomed. After the implementation, Katie told us, 'There were so many entry points in e-textiles. You can be good at one thing and not another, you find out who knows what and work together, which is really different from a straightforward programming unit.' Sergio noted, 'The ones that didn't excel in the class, the ones

who turned in work late, I saw those students helping in e-textiles. In the other units, the helpers were the A students, the B students. Here, it was anybody.' Amber concurred, 'E-textiles reached the girls having a hard time in other classes, those labeled as problem kids because they need hands-on experiences to focus. E-textiles got them motivated and working, they really dove in. They were helping other people and really having a good time.'

Teachers' aides and paraeducators also took on stronger roles as stakeholders in several classrooms, as their prior knowledge was valued. Jaime told us his paraeducator "felt empowered," noting, 'One of my aides is an older lady, not very good with computers. But she really likes sewing and she had so much fun this year! She showed a couple of the girls how to do it. She really liked having the kids come and ask her for help.'

B. Conceptions of Self: Teaching CS with Empathy

A common personality trait among the teachers was that they loved the challenge of learning new things and considered themselves lifelong learners. In ECS-lingo, they claimed they enjoyed taking their "teacher hats" off in PDs to advance their own content knowledge. This was demonstrated in their pre-interviews and in their feedback after each e-textiles PD. In particular, the PD feature that CS educators most valued was the time and space to do the projects. Jessica wrote: "I really like doing the projects before I do them with my students." Alana echoed: 'I like how the PD is focused on content first. As we create projects, we think about how we can teach.' Hervé commented on 'the effort it takes to create each project,' which gave Juan 'ideas on how to break down the unit projects for students to better serve them.' In the crafting activities, teachers 'encountered roadblocks' and 'saw where students might have issues,' then "figure out how to address them" 'before they occur with students in class.' Jaime came to the second PD with an incomplete project: 'My lights had gotten messed up the night before and I felt how my students feel when they're stressed out about an assignment; ashamed. It really helped me connect to my students, talk about a miserable experience!'

Reflecting on their own learning experiences in the workshops changed educators' manner with their students. Sergio admitted making a lot of mistakes in the PDs. He told us he frequently reassured his students, 'If you make mistakes in class, don't worry about it because I went through the same thing. It's okay.' Notably, the educators showed their own artifacts to build emotional bridges with their students—even projects that they were not proud of, challenging students to improve upon them. Yonatan said he repeatedly told his class, 'Not that long ago I was doing the same thing as you guys—I did not know how to sew before I started these projects!' He explained to us, 'You show them that you are human, you are just like them. When you relate to the kids, they think: If he did it, I can do it.' Jaime said, 'My wristband didn't work, so I showed it to them: This is where I started so it's okay if your sewing's not great!' For CS educators, demonstrating their own limitations and insecurities was a new way to participate in class and facilitate learning through modeling.

C. Conceptions of Students: Student-Driven Learning

A key feature of this curriculum was that artifacts are the maker's own designs, rather than makers being told what to make. However, as teachers crafted artifacts in PD, some struggled to come up with original ideas for their own projects. Those educators worried that students who are not naturally creative might need prompting. After PD3, Jessica asked fellow participants to share their projects in a Google folder as "examples to show students." However, by the end of the workshop series, the teachers expressed increasing excitement about seeing what their students would create, letting students drive their projects instead of referring them to a repository of teacher-crafted artifacts 'for ideas.'

In the classroom, our participants said they let students' own ideas and needs drive their in-class interactions during the curriculum implementation. They reported that a pivotal moment for both teachers and students was when the LEDs in students' projects lit up for the first time. According to the educators, many students demonstrated interest in advancing their computing, design, and crafting skills prompted by those moments. Also, when students "tested" their in-progress artifacts—powered their projects to see if their code functioned properly—they saw their own designs come alive. In those special "light up" moments, some students immediately expressed the desire to embellish and further accentuate the uniqueness of their projects. Other students treated their projects like prototypes and asked their instructors if they could start over and improve their designs (which teachers recognized was beyond the requirements and the resource capacity of the e-textiles curricular unit). Claudia was overjoyed to see her students 'running with it,' specifically, adding personalized touches and functions to make their projects distinct from their classmates' and improve upon their previous artifacts. The teachers let individual learners guide how they supported them, as the artifact design and creative processes were different for each student.

Our participants also saw that when students' own interests were centered, the students were more motivated to extend beyond previously-held mental limitations to complete their e-textiles projects. Teachers heard from their colleagues that students were sewing and drawing in their other classes as well. Students with inconsistent class attendance before the e-textiles unit commenced, began coming in to the ECS classroom to work on their projects outside of class. E-textiles encouraged many students to conceive of computational projects outside of class as well. For instance, Claudia reported that after the e-textiles unit ended, one of her students mentioned that he would apply LEDs to his graduation cap. "He's going to make it dance!" Claudia told us proudly.

D. Social Relations: Strengthening School-Home Connections

Teachers observed that when students made personally-relevant creations, they learned things about their students that they hadn't known before. In particular, strengthened communication and connections with students' mothers emerged as a frequent theme in the teachers' final interviews. Sergio said, 'I heard

more talking, socializing, talking about parents, like: My mom taught me this, like they took more pride.' Jaime was troubled about six boys who were failing his class. When he called their homes, all of the families responded enthusiastically when they learned that the boys' missing assignments were handcrafted projects. 'It was all moms that came' to the after-school tutoring sessions, to help their sons make up the work and pass Jaime's class. 'This was something they could actually help with, they were comfortable. One of the moms was like, 'This is so fun, this is great! I was like: You need to stop helping and let him do it!' Jaime reflected: 'The kids were really happy at the end; they didn't fail, which was great. In this community, parents are always willing to be here and help, but they sometimes don't know how to.' Claudia similarly suggested for students, 'Reach out to your grandparents, reach out to your aunts, your moms.'

E. Teaching Making is Fun… and Demanding!

The majority of the educators reported that teaching e-textiles was fun. They enjoyed letting go of their normative teacher roles and taking on a more "playful," "animated" facilitator personas. As teachers "worked the room," they observed more 'lightbulb-went-off' moments and celebrated these academic victories with their students. Claudia said the class made her laugh, which "was really different" from the other ECS units. Olivia 'was disappointed' that she could not help all of her students every day, a goal that other teachers shared. Jorge told us: 'With all these materials, I felt I needed to be checking everything, making sure students had what they needed. I walked more, I was a lot more active, I did more exercise!' Olivia said "I don't feel like I did a good job" if she sometimes couldn't check in with each individual: 'I think it really affected them.'

The educators also adapted the e-textiles curriculum to facilitate more joyful and empowering experiences for students. Time constraints and scaffolding prompted teachers to adjust project timelines, expectations, and assessment formats. For instance, Doreen modified an assignment to eliminate "busy-work:" 'I asked them to program three lights instead of four as a modification.' This change was necessary because she had extended the completion deadlines for two earlier projects so that her 'slower crafters' could finish their artifacts. Most of the educators had students work on their final projects in pairs or relaxed the requirement that all work is completed individually. Teachers were primed toward students experiencing a sense of accomplishment upon project completion, even if that meant that only one would take the finished artifact home. They worried about the severe lack of time and space, and wondered if paired students benefitted from one another's expertise (i.e., an excellent crafter would sew more efficiently, an exceptional programmer could write code faster with fewer bugs), to appreciate and uplift different skills and knowledges in class.

V. Discussion

A. E-textiles and Culturally Responsive Pedagogy

In a CRP approach, students' prior knowledges are the foundations for new learning [5], and e-textiles lessons can be a vehicle to center student-makers' subjective and culturally-situated ways knowing the world. Though our participants' narratives were distinct, the common report across schools was that introducing maker activities did in fact make space for CRP in computing. While we make no claims that this experience transformed teachers into culturally responsive pedagogues, based on the teachers' own observations, we found that e-textiles did help to honor expertise not typically acknowledged in computing classes, strengthen home-school relationships, and foster more authentic relationships with students.

Historically, so-called cerebral work is valued over manual work, creating a dichotomous ranking system that plays out in computing and in education. This false distinction influences which courses and students are tracked into academic or vocational pathways in secondary schools, for example. But as teachers and students created knowledge together around e-textiles, the shifted classroom culture helped to deconstruct typical notions of who belongs in computing by uplifting other kinds of knowledge and experience. Technical, hand-based skills that are not typically associated with coding, like the ability to identify short circuits or sew sensors in an aesthetically pleasing pattern, were just as valued as prior programming experience. This encouraged candid discussions about personal weaknesses, strengths, and problem-solving strategies to benefit students' final products. The students constructed a new digital knowledge economy in the classroom and developed techno-social abilities through the handcrafted projects [6]. They also blurred the hierarchies in which teachers, students, classroom aides, parents, and other school stakeholders traditionally operate and interact.

The participating teachers paid close attention to students' ideas to best advise them how to "run with" their conceptual designs and bring them to life. Emphasis on personalization at every stage of each project encouraged educators to not only learn from student expertise but learn about their students—what makes them unique, who they make for, what inspires them, what their hobbies are, etc.—which helped teachers relate to their students in new ways. The educators were also heartened and motivated to support their pupils who had not expressed comfort or confidence in prior ECS units, who seemingly suddenly were eager to engage in advanced programming content to complete their e-textiles projects. Computing classes were cooperative and livelier, and disrupted familiar stereotypes of social isolation and competitiveness that plague CS. Teaching this unit was fun and energizing for our educators.

Coupled with their own experiences in PD, connecting with the students through e-textiles uncovered a crucial emotional texture in our participants' culturally responsive approaches to teaching CS: *empathy*, the ability to place oneself in another's position, i.e., sharing the feelings of another from that person's frame of reference. The teachers shared the special "light up" moments with students and magnified the enthusiasm in the room as students' own skills, values, and individuality were manifested into visible, tangible artifacts that they could take home upon completion. The educators also expressed a deep appreciation for the discomfort and frustration experienced by learners ("I went through the same"), and highlighted the importance of productive failure, iteration, reflection as necessary elements of the creation process.

B. Pedagogical Challenges with E-textiles

Making the projects themselves in PD enhanced teacher empathy toward their learners, without which their ability to be culturally responsive in delivering e-textiles lessons might have been compromised. But one must consider the feasibility of providing extensive professional development to educators due to school budget and time constraints. Also, educators reported feeling very tired after teaching a period of e-textiles, even as engaging with students individually built stronger teacher-student relationships in the classroom. Sergio's ECS class had 45 students in a tiny modular (portable) classroom with desktop computers. Teachers were disappointed to not "check in" with students to ensure they all had what they needed to feel successful, especially in the 30-minute class periods in their alternating block-schedule. Lack of space forced students to craft on the floor, outside, and take work home; the effects of these conditions on the teachers' ability to provide culturally responsive pedagogy remained unmeasured.

Educators extended deadlines, making the curricular unit take longer than expected. They rushed through and modified some of the learning activities, taking shortcuts to ensure completed artifacts at the end of the unit. Some of their decisions may have effectively re-inscribed traditional computing roles and tasks. For example, assigning the final project in pairs may have relegated more experienced crafters to sewing and limiting their exposure to advanced programming content.

C. Limitations and Looking Ahead

This article primarily focused on teachers' own perceptions and appraisals of the e-textiles implementation. Analyses of the students' e-textiles learning experiences might reveal the impact of the instructional pedagogy on students, but this was outside the scope of our paper.[iv] Also, it is important to note that CRP is not an easily adoptable technique nor a checklist of instructional steps to follow. E-textiles materials and activities are not culturally responsive or democratizing on their own, and we caution practitioners from embracing maker-based lessons as a panacea. Rather, CRP requires active contestation of valued, dominant practices in CS education.

Lastly, the results of this study engaged only very lightly with the critical theories that guide the key sociopolitical dimensions of CRP work [5], because they were not emphasized in the PDs by the facilitators as an crucial element of e-textiles teaching and learning. An important future study could consider how e-textiles can be better leveraged to help computing educators address the societal hegemonies reflected in schools and in CS today.

VI. Conclusion

Broadening participation in computing requires a multi-step transformation in how students engage with CS content. In order for students to feel welcome and safe to study computing in historically inequitable, exclusive educational spaces, CS concepts and activities must center student expertise, be relevant to the students, and helpfully scaffolded. This study extended other efforts to engage students who are underrepresented in computing by examining lessons that were student-centered from the design phase to construction to debugging and artifact completion, made learning palpable and observable, and fostered creativity. Teachers reported how students made things that were personally meaningful to themselves, which encouraged teachers and pupils to interact in new "fun," collaborative ways in the classroom, to share interests, varied expertise, and different perspectives with one another in an authentic, reciprocal, and visible manner.

This study also marked a departure from earlier research on culturally responsive computing in that the educators did not provide nor sanction the use of ethnically-oriented design tools or heritage imagery and icons. Rather, all of the assignments in our e-textiles pilot were semi-structured and open to interpretation by the makers themselves, and used such items as needles, thread, fabric, and materials found ubiquitously all over the world across ethnic groupings. Thus, the teachers saw students draw from their own personal experiences, knowledge, and interests to make artifacts that expressed their own identities, not the researchers' or teachers' conceptions of what might interest the students. While e-textiles lessons and constructivist approaches to teaching computing were featured in this study, pedagogy, rather than a particular tool or activity, potentially has the most influential impact on student outcomes.

Our findings suggest that CS students and their educators should continue to be imaginative knowledge-makers through constructionist activities. When empathy, social connectedness, and an asset-based approach is used to build computing lessons on students' cultural knowledge, the classroom can be transformed into an inclusive and democratic learning environment for all. This requires educators to fundamentally examine how they engage with historically underrepresented students, by interrogating and reflecting on how they view themselves and their students, what knowledge is valued in their CS classes, and by fostering authentic social relationships with students in and out of the classroom.

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Notes

[i] Our preferred label is "culturally responsive pedagogy," though similar terms (culturally relevant, sensitive, centered, congruent, reflective, sustaining) have been used by scholars in the literature. See G. Gay, *Culturally responsive teaching: theory, research, and practice*. Teachers College Press, 2010.

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