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Weaving the Societal and the Technical into Teacher Experiences: Experienced computing high school teacher learning in an electronic textiles professional development session

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Abstract: Amongst efforts to realize computer science (CS) for all, recent critiques of racially biased technologies have emerged (e.g., facial recognition software), revealing a need to critically examine the interaction between computing solutions and societal factors. Yet within efforts to introduce K-12 students to such topics, studies examining *teachers'* learning of critical computing are rare. To understand how teachers learn to integrate societal issues within computing education, we analyzed video of a teacher professional development (PD) session with experienced computing teachers. Highlighting three particular episodes of conversation during PD, our analysis revealed how personal and classroom experiences—from making a sensor-based project to drawing on family and teaching experiences—tethered teachers' weaving of societal and technical aspects of CS and enabled reflections on their learning and pedagogy. We discuss the need for future PD efforts to build on teachers' experiences, draw in diverse teacher voices, and develop politicized trust among teachers.

Introduction

As CS moves into K-12 education, most PD, curriculum, and research efforts have focused on teaching and learning CS content: concepts to understand principles and processes of computers and software (Seehorn et al., 2011). Yet injustices amplified by computing applications (e.g., Benjamin, 2019) demand that equal attention be paid to computing's "impact on society" (Seehorn et al., 2011, p. 1). This call has initiated a critical turn in K-12 CS education (Kafai & Proctor, 2022; Ko et al., 2022) that advocates for moving beyond the oft-adopted value-free stance on computing. Through pedagogical frameworks, researchers recently have proposed similar critical shifts in K-12 curriculum (Kapor Center, 2021; Madkins et al., 2020). Integrating a critical stance with technical learning is important when racist logics are embedded in computing abstractions and algorithms in computing tools often employed to 'solve' societal issues around policing and justice (e.g., Benjamin, 2019).

While many studies concerning K-12 student learning have added discussion units or even whole courses to examine computing critically (e.g., Vakil, 2018), far fewer have focused on teacher preparation to teach social justice issues within computing classrooms. Most current efforts in computing teacher preparation concentrate on inducting teachers certified in other disciplines, focusing on building teachers' technical CS knowledge (Menekse, 2015). A few recent studies highlight the challenges teachers face as they integrate computing with societal issues such as race and gender (Everson et al., 2022) and how White teachers may evade and deflect conversations around race within teacher PD (Goode et al., 2020). These findings suggest the need to better understand how computing teachers can learn to engage with and integrate critical ideas while learning to teach computing.

In this paper, we turn our attention to teachers (rather than students) as learners of critical computing. We analyzed one PD session where experienced high school computing teachers learned to teach an electronic textiles (e-textiles) unit. This innovated session, developed by a teacher-facilitator, integrated technical aspects of designing sensor-based physical computing artifacts with societal concerns, such as racism, that are embedded within inadequately designed sensor-based devices. Inspired by interaction analysis (Erickson et al., 2017; Jordan & Henderson, 1995) and sociocultural theories of teacher learning (Vygotsky, 1987), we conducted a collaborative video analysis of the PD session (with six teachers as participants/learners) to answer the research question: how do teachers learn technical and societal aspects of computing while participating in an electronic textiles PD?

Background

The design of the PD and the ensuing data analysis were informed by sociocultural theories of teacher learning, PDs as sites for teacher learning, and the teacher learning of critical aspects within computing.

Theories of teacher learning

A sociocultural perspective of teacher learning highlights how situated, social and cultural aspects shape professional identity development (Fishman et al., 2014; Shulman, 1987). Shulman (1987) viewed teaching as a practice and teachers as a part of communities of practice with shared understandings of teaching. He further framed teacher learning as developing fluency with practices of teacher communities, in interactions with one another and in a distributed fashion with expertise distributed across teachers (Fishman et al., 2014). These theories posit that teachers do not learn discrete, disconnected facts or skills but learn concepts as they relate to their teaching contexts, classroom dynamics, and personal experiences (Bukor, 2014; Enyedy et al., 2006).

Classrooms and teacher PDs are two prominent sites of teacher learning studied within learning sciences (Fishman et al., 2014). Studies that have explored teacher learning in classroom settings have examined teachers' interactions with both resources (such as curricular materials) and students in shaping their practice (e.g., Sherin & Han, 2004). Similar efforts involving PDs have either focused on different facets of teacher knowledge (e.g., Shulman, 1987) or on the social nature of teacher learning and the development of communities of practice (Fishman et al., 2014). Though attention to processes of teacher learning during PDs is important, scarce research details processes of how teachers learn to critically engage with disciplines or ask questions about the relationship between disciplinary knowledge and its interactions with communities and societies. This gap is especially significant in the case of in-service, experienced teachers who rely on PDs for professional learning opportunities to grow their ability to teach critical computing (Fishman et al., 2015; Goode et al., 2020). While studies related to student learning have highlighted the importance of, for instance, politicized trust—a race-conscious way of understanding, respecting, and being in solidarity with one another—in shaping learning of critical aspects (Vakil & de Royston, 2019), similar examinations of learning processes within teacher PDs are lacking.

PDs as sites for computing teacher learning

Previous research within computing education has highlighted key PD aspects that shape teacher learning: duration of the PD, connections to classroom practice, focus on learning methods and pedagogical content knowledge, and relationships within school districts (Menekse, 2015). This aligns with Fishman and colleagues' (2014) review of teacher learning within learning sciences that emphasizes extended durations, opportunities for engagement with content knowledge, practice-related aspects such as student learning, and reflection. But most research on computing teacher learning relies on teacher surveys and interviews as methods, revealing very little about the processes of computing teacher learning (Menekse, 2015; Yadav et al., 2016). Further, prior studies within computing teacher PDs focus primarily on disciplinary knowledge as a collection of technical aspects (Menekse, 2015), barely interrogating how teachers learn to expand the disciplinary boundaries and integrate critical societal concerns with technical aspects. An exception is Goode and colleagues' (2020) examination of teacher learning of critical issues in computing through an analysis of teacher discussions and interactions within PDs. With increased computing tools around us and heightened implications for marginalized communities (e.g., Benjamin, 2019), teacher preparation efforts should support teachers in critically engaging with societal impacts of computing. Recent equity-centered computing pedagogical frameworks underscore the need to "situate technology ideas within their sociopolitical context and give students opportunities to critique and explore issues that are relevant to them" (Madkins et al., 2020, p. 13). Buttressing this call, Goode and colleagues' (2020) study surfaces the need to support experienced high school computing teachers in engaging with societal aspects such as race during PDs. While limited prior studies highlight the struggles of teachers as they integrate technical and societal aspects (e.g., Everson et al., 2022; Goode et al., 2020), there is a need to further understand how to support teachers in critically analyzing the connections of societal and technical dimensions of computing.

Critical computing teacher learning

Mathematics and science education have explored how to engage teachers critically (Bianchini et al., 2015), laying a path for examining learning of critical computing. Questioning the relationships between computing, people, communities, and societies can support students who belong to historically excluded groups find their voices, engage with the discipline in personally meaningful ways, and contribute agentically to the discipline (Goode et al., 2020; Vakil, 2018). With concerns of teachers evading or deflecting race-related issues or blaming individual students for failures that have roots in historical and systemic racial oppression (Segall & Garrett, 2013), teachers should engage with societal issues such as race and racism, gender, and ability in computing.

While prior studies have proposed equity-centered pedagogies (Madkins et al., 2020) and critical pedagogical frameworks in computing (Kapor Center, 2021), we know very little about how teachers learn or develop critical perspectives at the intersection of technical and societal aspects of computing. Most efforts have been additive in nature—i.e., introducing the societal aspects in addition to the technical aspects—rather than integrating social and technical dimensions (e.g., DeHart, 2022). In other efforts where race-based conversations were purposefully integrated into teacher PDs, race-related issues were discussed in terms of recruitment and retention of students from marginalized groups—i.e., working on strategies to remedy the structural lack of opportunities—while computing concepts and constructs were discussed separately from how computing algorithms may encode racism and have implications for users from marginalized communities (Goode et al., 2020). Integrative approaches that consider programs and algorithms hand in hand with societal aspects that shape them, rarely studied, are limited to researcher suggestions of potential classroom activities and examples (e.g., Ko et al., 2022) rather than explored in action in PDs. Thus, we know very little about what goes on within such PDs, despite recent calls to integrate the societal and technical concerns and shift away from an additive approach of disconnected modules on equity and social justice within computing (Goode et al., 2020; Ko et al., 2022).

Methods

Context and participants

This study was conducted with the *Exploring Computer Science (ECS)* teacher community, developed over 10+ years to support teachers to teach *ECS* curriculum (an introductory computing course) built on three pillars: computing concepts, equity, and pedagogy (Goode et al., 2012). PDs involve a weeklong session for two summers with four day-long quarterly sessions between the two. Previous research has found this model useful to develop teacher communities (Goode et al., 2014). With electronic textiles (e-textiles) offered as an optional unit within *ECS* (Kafai et al., 2019), the e-textiles online PD was designed along similar lines: *ECS* teachers with prior e-textile teaching experience facilitated summer and quarterly sessions for *ECS* teachers new to e-textiles. As a part of a research-practice partnership (RPP), the PD had a diverse group of participants: university researchers and a non-profit partner, e-textiles-experienced teachers who were teacher-facilitators, and e-textiles-beginner teachers who were teacher-learners. Annie, Davon, Elisa, Julie, Leah, Maggie, Maria, and Leisha (all pseudonyms) were the teacher-learners with a wide range of experience teaching *ECS* (see Table 1 for their racial and gender identities, teaching experience and contexts). We analyzed teacher interactions during one of the quarterly PD sessions where teachers, except Maria and Leisha (*unable to attend this session), worked on a sensor-based e-textiles Human Sensor project and discussed technical and societal topics around it.

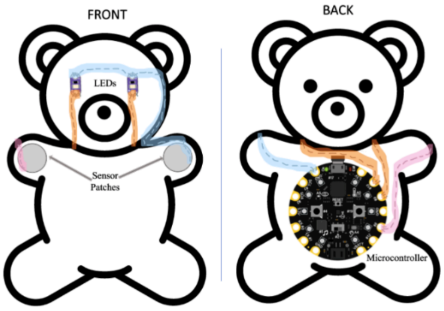
Yasmin and Joanna were senior researchers. Deborah and Gail, also senior researchers, partnered with teacher-facilitators to design and implement the PD. Kate works for a non-profit organization responsible for supporting PD online. Ben and Jesse, with Angela (not present during this session) were *ECS* teacher-facilitators with 4-6 years of e-textiles experience teaching. Ben facilitated the session on Human Sensor project. Leo, Mia (not present during this session), and Gayithri were three graduate student researchers. All of us identify as cis-women or cis-men. Among cis-women, Gail, Joanna, Deborah, and Kate identify as White, Gayithri as South Asian, Mia as Black, Angela as Asian-American, and Yasmin as Indo-European. Among cis-male, Ben identifies as White, Jesse as Latino-European, and Leo as Latino. Shaped by our teaching, learning, and research experiences within CS across diverse contexts, we are committed to center justice in CS education.

Table 1
Teacher-learner details.

Teacher name (Pseudonym)	Racial and gender identity	Teaching experience (years)	Teaching geography in the US	Student diversity[#]
Annie	White, female	26	Midwest suburban	40% RM; 30% FRL
Davon	Black, male	3	Southeast city	100% FRL
Elisa	White, female	10+	Northeast suburban	4% RM
Julie	White, female	19	Northeast suburban	33% RM; 20% FRL
Leah	White, female	28	Midwest suburban	7% RM; affluent
Maggie	White & Hispanic, female	8	Midwest city	Majority RM
Maria*	Black, female	6+	Midwest city	99% RM; 91% FRL
Leisha*	Black, female	20+	Southeast rural town	99% RM

The teacher-learners were working on the Human sensor project as a part of the constructionist-driven e-textiles unit (Kafai & Fields, 2019). As shown in Fig. 1 (left), it required sewing a pair of aluminum patches to act as analog touch sensors when connected to the microcontroller pins and programmed using an Arduino programming environment. The teacher-facilitator team chose the lesson about computationally testing different sizes of aluminum patches as an opportunity for conversations about inclusivity of diverse users. By then, teachers had designed circuits and aesthetics to make 3-dimensional soft toys that would respond to different degrees of touch (no touch, soft, medium, and hard press). They tested sensors with family members and noted down the range of sensor values for different sizes of sensors (small, medium, big, Fig. 1, right). The session after sensor testing was chosen for analysis since Ben orchestrated a conversation involving social and technical aspects of computing.

Figure 1
A human sensor project template (left) and analog sensor readings (right).



Name	Small		Medium		Large	
	Low	High	Low	High	Low	High
Davon	311	800	670	945	521	1023
Annie	891	1023	946	1023	775	1023
Maggie	698	1023	726	1023	951	1023
Yuri	683	1023	414	1023	450	1023
Dahlia	701	1023	746	1023	782	1023
Julie	882	1023	821	1023	762	1023
Leah	892	1023	834	1023	690	1023
Leah's Dad	978	1023	964	1023	875	1023
Frankie	696	1023	601	1023	471	1023
DJ	888	1023	835	1023	707	1023
Elisa	1008	1023	1009	1023	1005	1023
Tangela	867	1023			881	1023
Keira	651	1021			758	1021

Data collection and analysis

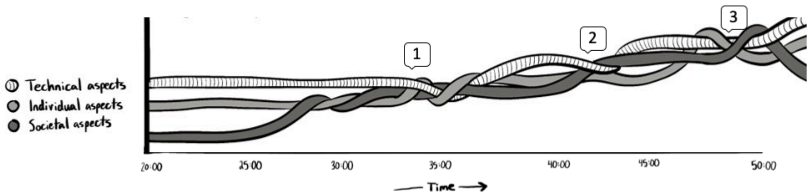
Screen recording of the online PD session (45 min.) is the primary data source. PD materials such as session agenda, teacher project designs, and teacher pre-PD interviews were analyzed to provide the video with context. As a first step, Gayithri analyzed teacher pre-PD interviews for teacher backgrounds and teaching contexts and examined project designs and the session agenda to contextualize conversations. The teacher group was the unit of analysis with a focus on group meaning making as discussions ensued during the session.

Inspired by interaction analysis (Jordan & Henderson, 1995), Gayithri structured collaborative video analysis (Erickson et al., 2017) supplemented by repeated individual viewing and interaction with the transcript. In this online PD session, interactions were multimodal, including verbal utterances, text-based chat, and screenshares, with embodied participation less visible. Gayithri initially viewed the video to prepare a multimodal transcript to capture talk, gestures, facial expressions, chat entries, and entries on shared documents. The transcript was elaborated with comments during three ~2-hour long iterative group viewing sessions attended by the author team. This allowed for cross-expertise discussions and exchanges of perspectives during video analysis (Erickson et al., 2017). The multimodal transcript served as a shared artifact that viewers interacted with while watching the video together, pausing the video for notetaking whenever required. Joint viewing sessions helped us identify three key episodes where the technical and societal dimensions interweaved in teacher discussions. Gayithri followed up with individual viewing sessions, rewatching the video in relation to the comments gathered, particularly to answer the research question. A visualization of the dynamics of the video was generated collaboratively by Mia and Gayithri (Fig. 2) that represented the flow of the session, particularly how different aspects were initially individually discussed and then interweaved across the three episodes. The visualization was shared with the analysis group for further engagement with the emerging themes.

Findings

Teachers engaged with critical computing as they discussed inequities in technical designs and implications for diverse users within the context of their human sensor projects and real-world technologies, while anchoring discussions in their personal and classroom experiences (Fig. 2 for visualization). Below we elaborate three episodes to demonstrate how teachers integrated the technical and the social aspects of computing, and how their experiences tethered their learning, supported by a trimmed version of the verbal transcript due to space limitation.

Figure 2
A visualization of the flow of the session.



Episode 1: Do you think everybody will be able to use your device the same?

During this episode, teachers grappled with technical decision-making around sensor value ranges within their individual projects and the implications of those decisions on different users. Upon designing the aesthetics, teachers had to determine the size of the analog sensor patches for their projects and program them to allow users to interact with them and generate four different light patterns. Towards that end, teachers were tasked with testing sensor patches of different sizes (small, medium, and large) with any family members around and noting the lowest and the highest values (Fig. 1, right). Ben asked teachers to determine four sensor value ranges that could be included within their programs to correspond to the four lighting patterns caused by different degrees of touch.

After the teachers determined the sensor ranges, Ben moved their attention towards the social aspects of the design. Connecting the numerical values to implications for users, he asked if "everybody will be able to use [the] device the same [way]?" (Table 2). While teachers had grappled with the dimensions of programming sensors at an individual level until now, they had to extend their individual observations and reasoning across their colleagues' datasets and discuss the human/social dimensions of these choices as they related to people who might interact with their projects. Design decisions, in this case, were couched inside the objective of not just making a functional project but one that includes diverse users. This brought in the broader societal issues of technology design in conversation with the technical details of programming, issues around who can and cannot use their projects. Teachers reasoned their choice of sensor value ranges in relation to their observations of their family members testing the sensors earlier and discussed implications of their decisions on such interactions. For instance, Davon noticed the effort it took him to realize a particular low value, reflected on how it might be difficult for Maggie's child who may not be able to exert the same pressure on the sensor. He said this led him to include the 0-500 range in his program to accommodate similar users. Maggie discussed her observations of her and her children's interactions with the sensor in terms of individual physiology and meaning making of possible interactions. Further, Davon acknowledged the limitation of sensor testing, i.e., he was the only person who tested his sensors (Fig. 1, right) and how that further shaped his decisions around sensor value ranges for his project. Overall, in bringing the technical aspect of programming analog sensors in relation to users' interactions and experiences, social aspects were no longer a modularized concern but deeply integrated with the project code.

Table 2
Episode 1 transcript excerpt at 34:24.

Verbal transcript	Verbal transcript
Ben: **Do you think that everybody would be able to use your device the same?** *Elisa, Maggie, and Leah shake their head to tell no.* Davon: Probably not [unmuted by mistake]. Oh! Ben: So why don't you talk to me, why not? What differences do you see? How are the decisions that we make in these light patterns going to manifest in terms of how people use the thing that we're making? Davon: Well, I know for me like I'm using the regular one [medium-sized patch], so I don't know… I had to squeeze real hard just to get my lower numbers, **somebody might not be able to squeeze.** Ben: [reading from chat] Your light pattern four is from zero to 500 right. Did anyone get down to below 500? Maggie: I didn't but my daughter did. And, so in our case, at home, we all did it differently. I was pressing on top of the table. My oldest was holding and squeezing…	Maggie: And then, the youngest was just like, barely touching it. No, I don't think we'll all get the same, because we all did it differently… **it depends on the individual**, it depends on how they want to do it… all those little details I think matter. Ben: So, it sounds like there are differences in terms of individual physiology, number one. Number two, the cultural ideas of how we do the thing… There's an environmental aspect possible like maybe if you're in like a drier area, things might be different than if you're like in a wetter area… there could be some other things happening here and it's all completely individualized. Davon: Yeah, and that's what I was trying to say… my strength might be stronger than a child, Maggie's child, you know, was different. So that's why I didn't want to eliminate that 500 and below because you never know… because **we're just one person that kind of check the data**. Ben: I love what you're saying.

Episode 2: Everyday technologies that are not inclusive

In addition to connecting sensor ranges to user interactions within e-textiles projects, teachers continued to weave societal and technical aspects as they discussed various sensor-based technologies that excluded or caused ineffective outcomes for certain user groups. Conversations around inclusive design of individual projects in the previous episode shifted to everyday technologies that "did not think through inclusiveness" (Table 3). Teachers drew from a range of personal connections and discussed how technologies in their lives did not include marginalized populations. For instance, Leah mentioned cell phone touch screens that assume certain physiological characteristics such as shape and sensitivity, and Elisa shared the lack of consideration of human aspects in the design of motion-sensor lights in her classroom. Further, Julie shared about her five-year-old with Down's syndrome and his struggle with voice assistants like Alexa.

However, lively conversations only occurred when teachers related their lived experiences. Otherwise, there was awkward silence. For instance, teachers barely engaged when Deborah and Ben presented examples from outside personal experience, such as pulse oximeters that "don't work well for dark-skinned people" and airport scanners that have "a much higher significant hit on Black women's hair" respectively. Perhaps bringing in external sources disrupted the conversation or perhaps the lack of personal connections among teachers in the room triggered the silence. Except Davon, all other teachers in the room identified as non-Black and not dark-skinned (two Black female teachers were absent: Maria and Leisha, see Table 1) which could have led to silence around topics related to Black community's interaction with technology. This alludes to the need for diverse teacher experiences within PDs and supporting non-Black teachers to engage with race-related topics.

Table 3
Episode 2 transcript excerpt at 40:49.

Verbal transcript	Verbal transcript
Ben: Can anyone think of any **technologies that you work with every day that did not think through inclusiveness**, where there might be some users who might not be able to use the device based upon some physical or cultural or human things? Leah: I would say, touch screens on cell phones and individuals who have like large fingers, or their fingers are starting to lose sensation, and **it's really difficult to accurately press the right keys on those keyboards**. Ben: Yeah… For sure. What else? What are some other examples that you know that you might notice differences in how people interact the technology? Elisa: So, lights in my classroom. Well, one of my classrooms, goes off and like leaves me in the dark and it's not enough to do this [waving hand]. I have to get up and walk to the right place. Ben: So, **the sensor on your light was not designed with your configuration in mind.** Elisa: **With actual people probably** [laughs] Ben: [laughs] With actual people in mind. Julie: My son, my five-year-old has Down's syndrome, so we have a lot of adaptive technology and a lot of adaptive supplies like scissors, for example, is something that's adaptive because he doesn't have as much strength, so he has special scissors. But as far as tech go, like higher tech, you know, **Alexa is really hard for him to communicate with**…	Julie: I think Google somewhere in Canada, they're having people with Down's syndrome… collecting different people speeches to try to advance those technologies. Ben: Does anybody else here, or their family have challenges with using Alexa, or Google or any of those speaking technologies? [Ben raises hand in response to his question, and other teachers including Davon, Leah raise their hands too. Julie smiles and nods in agreement] Ben: Yeah, my grandma was from Russia, and good god trying to watch her try to integrate with Alexa… really frustrating for her, because it didn't understand her very, very thick accent… I've seen Texans struggle with Alexa… you think that the only foreign people can't use. No, no, like, people, people in Boston have difficulty with Alexa, because it doesn't know what about a car [in Boston accent] is. Ben: The sensors that measure oxygen by touching your fingers the pulse oximeter [reading from the chat]. What about that Deborah? Deborah: Well, **they don't work as well for darker skinned individuals**… So, clearly their user sample's not very great. Ben: Or for example, those things in the airport, they go around you like that zzzz, to make sure that there's nothing on you. **There's a much higher significant hit on Black women's hair**. So, if you are a Black woman going through that security system, you have a significantly higher chance of being removed from line. [**silence in the room**]

Episode 3: Experiences as a tether

Throughout, personal and classroom experiences tethered teachers' weaving of societal with technical aspects. Making the project put the teachers in students' shoes and enabled reflections on their learning and pedagogy (Episode 1). Building on Episode 2, teachers drew from their personal experiences with everyday technologies to identify bias. Drawing these together, Ben prompted teachers to "link" between the two (Table 4). Coming back to technical implications around determining sensor ranges in their projects, teachers concluded the need for "inclusive sample for testing" and again grounded conversation in their personal experiences.

When Ben encouraged teachers to connect classroom practice and think about supporting their students to do the same, teachers drew from their prior teaching and learning experiences to derive lessons for classroom practice. Of particular note, Annie shared how her students in a different class designed a pair of sunglasses without considering gender diversity among testers (Table 4). Narrating this instance, Annie reflected on her knowledge of her students and how she "ignorantly… thought [her students] would get inclusive feedback." She instead concluded that "it's very important to help kids understand who should be in the sample size." Not visible in the transcript, other teachers like Leah discussed other pedagogical approaches such as asking "who's missing in the sample data" to support students through critical computing. Overall teachers' experiences—technical, personal and classroom—acted as a tether to learn to integrate technical with societal concerns during the PD.

Table 4
Episode 3 transcript excerpt at 46:15.

Verbal transcript	Verbal transcript
Ben: So, how is this conversation, based upon the activity that we just did, **what's the link?** Ben: [reading from the chat] Making sure we're being inclusive in our, in our designing.... So how having a mindset for that we need to be purposeful in our designs. Leah says using an inclusive sample for testing. **Was our sample inclusive?** If we were trying to create a product for all people in the United States, is our sample, inclusive enough? Davon: No. Ben: Yeah, so maybe the people that you're sampling needs to broaden, maybe we need to bring more people in when we test. Absolutely... **What would you do in your classes, in this moment, to bring out this conversation, to bring out these ideas?** How would you handle it, would you handle it? Do you think that this is a moment that's important, and that needs to happen? Annie: **I just have to share this happened in my class this week.** I teach a manufacturing class. And, it's all boys and a male teacher and me. And one of my groups are manufacturing wooden sunglasses. So, they've made some different prototypes of these sunglasses and their challenge this past week, was to test them with their friends… get some feedback. So, then they came back and they said yep, you know, based on all of our feedback, this is what we're going to go with…	Annie: And then they're working with a local company in town to actually manufacture 100 of these prototyped sunglasses. So, they said they're ready to go, they've done their research. So, I said, well, you didn't ask me to try them yet. So, I said let me try them and give them feedback, and I put them on and they immediately fell off my face. And I said you guys. I don't think we're good yet to say, we have 100 of these, like, let's talk about the sample of who you checked with. Well, then talking with them and in my ignorance when I said go ask your friends go out to the cafeteria get feedback. **I thought they would get inclusive feedback**. They only tried them on other boys. So, and other boys their age, who have a different head size than me. So, I said—now we're going to classrooms throughout the building and asking people through it out different classes. And, so we actually talked about sample size… We have to come up with sample sizes that are inclusive. Ben: Talking about sample, when we're talking about design. Annie: Right. Very much so **it's very important to design and helping the kids understand *who* should be in that sample size**. Because I mistakenly thought they would have a broad representation, and then they didn't on their own. And I think some of these companies too, you know, you think you're good. And then all of a sudden, oh wait, we're not good.

Limitations

A limitation of this study is the context which involved a particular group of teachers—experienced *ECS* teachers with an established sense of community, developed while attending *ECS* PD sessions together in the past. Further, they were attuned to equity and justice issues in computing education as they read and discussed *Stuck in the Shallow End* (Margolis et al., 2017) in *ECS* PDs and developed politicized trust (Goode et al., 2020). The findings presented above are couched in this context and further research is needed to understand how these findings relate to PDs with teachers not necessarily having already established relationships and commitment to equity.

Discussions and conclusions

This analysis sheds light on dimensions of PD activities that can support teachers to engage critically with STEM disciplines like computing. Across the three episodes, teachers made connections with their lived and classroom experiences as they engaged with issues of technology design with implications for diverse users. The significant role played by teachers' personal experiences is comparable to earlier studies (Bianchini et al., 2015; Bukor, 2014). In cases where such connections were absent, as seen in episode two, teachers struggled to converse about critical issues brought up by leaders. This connects with prior research that revealed the struggles of White teachers in engaging with race-related conversations within computing PDs (Goode et al., 2020). Of note, even in our group of six teachers—four White—who had experience with discourses of equity through prior PDs (which they had all led), personal experience seemed particularly important for grounding both technical and societal sides of conversations. Future PDs need to consider how to build on teachers' lived experiences and create new experiences, draw in diverse teacher voices, and develop politicized trust among teachers.

Having diverse perspectives in PDs helps build thought-provoking interactions (as noted in episodes two and three), just as diverse technology design teams mitigate biases in technology design. As teachers build on their personal experiences from their lives and classrooms during PDs, having diversity along those lines will expand the accounts discussed in PD settings, just as Julie's personal experience with her child's use of voice assistants brought in a particular perspective to discussions around inclusive design of technologies and projects in episode two or Annie's classroom experience added a particular perspective in episode three.

Yet another key contribution of this analysis are the contextual factors that shaped the findings, in particular, creating a common project (like the human sensor e-textile project) and building on existing teacher relationships with politicized trust (from earlier shared PD experiences). Sensor-based devices, by their design, can encode inequities based on who's included in user-testing and who's left out (e.g., Benjamin, 2019). The e-textile human sensor project, which involved programming analog sensors, enabled teachers to discuss and consider programming aspects with broader societal issues around sensor testing and to connect with the larger issue of myopically designed sensor-based devices such as voice assistants, enabling conversations grounded in but extending beyond e-textiles. At the same time, this focused hour of PD built on six prior days of relational work, with shared crafting times, reflections, family interruptions (characteristic of long video calls) and other shared experiences, including an explicit invitation to test their sensors with others in their household members. Combined, these shared technical and social experiences made room for teachers to grapple with issues of inclusive design while trusting the space as safe to discuss their perspectives. Doing similar work with other teachers in other contexts will mean designing and creating such spaces for teachers to engage in similar ways. Sharing materials like a book, e.g., *Stuck in the Shallow End* (Margolis et al., 2017), that allow for political conversations in relation to the discipline (Goode et al., 2020) and creating technical projects, such as the human sensor project, lay the groundwork for disciplinary integration. Building relationships over many days, as the *ECS* model does across 14 days over two years, can provide the grounding for tethering technical, personal and societal aspects of computing. These combined technical and relational underpinnings will allow for integration beyond the more traditional additive or modular means of bringing up equity and justice-related issues in computing-like disciplines (DeHart, 2022). Many more future PD and teacher-learning studies are needed to explore integrating societal issues with computing content in the effort to bring critical computing to the fore in K-12 education.

Endnotes

(*) Teachers could not be present during the session analyzed; (#) RM == Racial Minority; FRL = Free and Reduced Lunch.

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