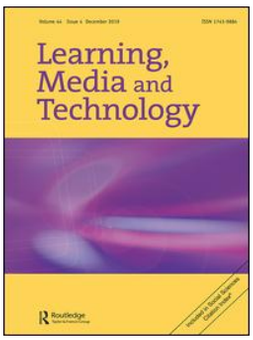

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pH empowered: community participation in culturally responsive computing education

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ABSTRACT

Culturally responsive computing (CRC) frames the localized knowledges and practices of Black, Brown, and Indigenous communities as assets for working toward racial justice in science, technology, engineering, and mathematics (STEM). A key part of CRC is the role that local communities play in designing and/or implementing curricula and technologies. Yet, there is a dearth of research on collaborating with local knowledge experts and what they think about CRC. In response, this paper details a two-year long research project on the design and implementation of one CRC program called pH Empowered. pH Empowered uses computing to bridge Black hairstyling, chemistry, and entrepreneurship. Through a mixed-methods study of one pH Empowered professional development workshop, we show how cosmetologists, urban farmers, and librarians had diverse perspectives about how to be culturally responsive with STEM and the racial justice goal of broadening participation in STEM education.

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Culturally responsive computing; STEM education; funds of knowledge; broadening participation; race

Introduction

There is a growing acknowledgement among U.S. educators, policy makers, and researchers that the underrepresentation of African Americans, Latinxs, and Native Americans in professionalized science, technology, engineering, and mathematics (STEM) is the result of economic, political, and social injustices that have limited their participation. The underrepresentation in computer science (CS), for example, is clear: of the institutions of higher education that responded to the 2018 Taulbee Survey, African American women were approximately 1% of the female recipients of CS master's degrees (Zweben and Bizot 2019, 17). The reasons for underrepresentation are specific to CS – e.g., 'shallow' computing curricula offered in K-12 schools that serve communities of color (Margolis et al. 2008) – and more general – e.g., the wealth gap between Black and White communities (Oliver and Shapiro 2006). In the context of CS education and employment the result is 'computing segregation' (Goode 2007, 71). Educators and researchers have sought to confront twenty-first-century racialized computing segregation by turning to culture-based and anti-racist strategies for teaching and learning. This paper focuses on one example, *culturally responsive computing* (CRC).

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CRC builds on anti-deficit framings of Black, Brown, and Indigenous children, adults, and communities from culturally responsive teaching (Gay 2018), culturally relevant pedagogy (Ladson-Billings 2014), culturally sustaining pedagogies (Paris 2012), and other anti-racist challenges to White supremacy and Eurocentrism in U.S. schools. CRC uses the educational affordances of computing technologies and computational thinking to show that the cultural practices, heritages, and knowledges of communities of color are important assets for broadening participation in STEM (Eglash, Gilbert, and Foster 2013; Scott, Sheridan, and Clark 2015). While CRC is part of larger broadening participation efforts, it does not start or stop with inclusion and diversity; it seeks to critique and challenge the very structural conditions (e.g., racism, poverty, sexism, colonialism, etc.) that produce marginalization and underrepresentation in the first place (Moreno Sandoval 2013; Vilchis, Scott, and Besaw 2015; Bennett 2016; Eglash et al. 2017; Lachney 2017a; Cooke et al. 2019; Scott and Elliott 2020).

Building on prior justice- and equity-oriented computing education research (Ryoo et al. 2013; Kafai et al. 2014; Scott and Garcia 2016), this paper uses González's (1995) concept of *funds of knowledge* – i.e., knowledge that is historically situated and practice-based within a given set of contingent community dynamics – to help conceptualize CRC as multi-directional flows of material and epistemic resources between STEM education and local communities. For some CRC projects, these multi-directional flows are supported by contributions from local activists, artisans, elders, culture-based entrepreneurs, and other adult community members who use their situated knowledge and expertise to help design STEM curricula and technologies that are both culturally and computationally rich (Bennett et al. 2016; Moreno Sandoval 2019; Eglash et al. 2020; Lachney and Yadav 2020; Lachney et al. 2021). Yet, there is little research on what adults who have relevant funds of knowledge think about the assumptions and goals of CRC.

In response, this paper details a two-year long project where researchers collaborated with local knowledge experts in the design of a CRC program called pH Empowered. The research culminated in a mixed-methods study of a CRC professional development workshop with cosmetologists, urban farmers, and librarians/educators ($n = 16$). All were novice programmers or non-programmers but interested in using their positionalities, knowledges, and expertise to support the use of computers in STEM education for their local communities. Our findings show that not only were there varying perspectives among the workshop participants with different expertise on how their knowledge connected to STEM and the goals of broadening participation, but also sometimes differences among individuals with similar expertise. We discuss how researchers can learn from local knowledge experts' insights about STEM and broadening participation, folding what they teach back onto CRC research and education.

Culturally responsive computing

In the design and implementation of CRC programs, researchers and educators sometimes draw on frameworks of *intersectionality* (e.g., Scott, Sheridan, and Clark 2015; Ashcraft, Eger, and Scott 2017; Garcia, Fernández, and Okonkwo 2020). Intersectionality grew and continues to grow from Black feminist scholarship in legal studies, sociology, and other disciplines, as well as social movements and activism (Hancock 2016). These works focus on the multiple forms of discrimination and marginalization that shape the experiences and identities of Black women and other women of color (Collins 1990; Crenshaw 1990). Intersectionality can be thought of as both a metaphor and heuristic (Collins 2019). As a metaphor, intersectionality supports interconnected and crisscrossing ways of thinking and forms of analysis, situating experiences of oppression within matrices of sociopolitical forces. It resists the idea that systems of power can be reduced to just race and racism, sex and sexism, and so on. Instead, intersectionality is about analyses of power where individuals, groups, institutions, and social categories (e.g., gender, race, class, dis/ability, nationality, etc.) are in co-constituting relationships (Grzanka 2019). As a heuristic, these ways of thinking can be used as part of anti-racist strategies to help rearrange our social and material worlds in more

just and equitable ways. A unique insight from intersectional perspectives is that strategies for change need to attend to the social identity categories and power dynamics that are relevant to and situated within particular times and places (Ruíz 2018). For example, the challenges that Black women face in twenty-first-century U.S. STEM fields are going to be similar to and different from both White women and Black men, necessitating responses that are based on historical and political understandings of those differences (Rankin and Thomas 2019; Rankin, Thomas, and Joseph 2020; Scott and Elliott 2020).

For CRC in the twenty-first-century U.S., the metaphor and heuristic have been applied to strategies for broadening the participation of Black and Brown girls and young women in STEM education (Scott and Garcia 2016; Pinkard et al. 2017). Scott, Sheridan, and Clark (2015) explain that CRC must attend to the concept and frameworks of intersectionality in efforts to engage with the power dynamics and political identities that are inevitably part of technology and education. Scott and colleagues' COMPUGIRLS program supports the development of technology and computing literacies through activities where girls and young women of color use their own positionalities and identities as foundations for becoming techno-social change agents within their own virtual and/or physical communities (Scott and White 2013; Garcia and Scott 2016). They argue that without explicit attention to the multiple axes of discrimination and power in technology education programs, they could end up reproducing existing inequities and myopic narratives about gender, race, and technology (Ashcraft, Eger, and Scott 2017). In another example, Pinkard and colleagues use intersectional metaphors to help explore how their program Digital Youth Divas builds on the prior experiences, interests, identities, and communities of girls of color as inspiration for digital storytelling that supports STEM agency and challenges negative stereotypes (Pinkard et al. 2017). In these cases and others, intersectionality helps to reveal how the unique knowledges that are produced from the identities, experiences, and communities of the girls and young women can become foundations for meaningful STEM engagement.

Another strand of CRC research is focused on the design of technologies. Too often technologies reproduce racist social norms and Eurocentric cultural values (Winner 1980; Lachney 2017b; Noble 2018; Benjamin 2019). Counter to these dominant elements of U.S. society and culture, Pinkard (1999) and Eglash et al. (2006) have demonstrated how the cultural capital of communities of color can be designed into educational technologies themselves. While the idea or concept of *capital* is often used in reference to economic capital, this only describes one type of exchange or wealth that shapes people's opportunities for social mobility (Bourdieu and Passeron 1977). In addition to economic capital there is cultural capital: the learned knowledges and skills that a person amasses to demonstrate status and accomplishments (Bourdieu 1986). All communities have cultural knowledges and skills, but only certain types – in the U.S., largely those that are amassed by White middle- and upper-class communities – are elevated by mainstream schooling and readily transferable into economic wealth. This creates the false impression and deficit orientation that some communities are rich in cultural capital while others are poor (Yosso 2005). In developing the concept of *community cultural wealth,* Yosso (2013) challenges this idea by showing that despite being blocked from economic access in the U.S., marginalized communities of color are rich in other forms of wealth: aspirational capital, cultural capital, familial capital, linguistic capital, navigational capital, resistant capital, and social capital.

As noted above, CRC researchers and technologists have found unique ways to leverage the cultural capital of communities of color in technology design and development. For example, take Pinkard's (2001) two computational learning environments: *Rappin' Reader* and *Say Say Oh Playmate.* They build on African American children's knowledge of rap lyrics and clap-routines, respectively, to support literacy education. On pre/post measures, Pinkard (2001) found that students had vocabulary gains after using these applications. Working within the field of ethnomathematics, Eglash (1999) has explored the ways that some African epistemologies and material cultures have intentional design themes behind them that are remarkably similar to fractal geometry. In the context of a high school computing classroom, Eglash et al. (2011) used a quasi-experimental design to

examine the influence of an *African Fractals* design tool on the learning of mostly African American and Latinx youth. They found that youth who learned about fractals in their original African contexts scored higher on post-survey measures for 'attitude' and 'performance' than those who did not.

Some CRC researchers and educators who draw on the ideas of intersectionality and/or cultural capital have referred to locally and culturally situated experiences and expertise (of youth and adults) as 'funds of knowledge' (e.g., Kafai et al. 2014; Scott and Garcia 2016; Lachney 2017a). The concept of *funds of knowledge* comes from research and theorization on integrating household and familial expertise of Southwestern U.S. working-class Mexican communities (e.g., linguistic expertise, labor expertise, etc.) into classrooms (Moll et al. 1992). Since this initial research, the concept has been extended to include the knowledges of other marginalized communities of color (González 1995). Along with many in the anthropology and education communities, González, Moll, and Amanti (2005) were dissatisfied with how the concept of *culture* all too often treats community and individual identities as unified and static, which risks reifying harmful stereotypes. Alternatively, they constructed the concept of funds of knowledge around the skills and practices of local communities, families, and households. They were interested in the actions that were taking place in students' homes and everyday lives, as well as how people were thinking and talking about those actions. The goal was to challenge static views of culture: 'we opened up a panorama of the interculturality of households, that is, how households draw from multiple cultural systems and use these systems as strategic resources' (González, Moll, and Amanti 2005, 10). Crucial to exchanges in these cultural systems are the historical, political, and economic relationships between home and work: 'The jobs that people work often provide them with a varied and extensive wealth of information' (González, Moll, and Amanti 2005, 12). The fungibility of skills and practices between workplaces and households can relate to activities around gardening, cooking, hairstyling, and other funds of knowledge.

This critique of culture is important for CRC researchers and educators if they are going to foster meaningful socio-technical experiences that connect STEM education to the practices and knowledges of local communities of color. Static views of culture have been used to reinforce institutional racism and racialized education hierarchies, rooting students' personal and community assets in the past without attending to their current contexts and how they can be used to help young people shape their futures (Vithal and Skovsmose 1997). Robust and activity oriented notions of culture are needed to resist conflating culture with race and treating it as a surface gloss on educational content. It is helpful for CRC to approach culture through the lens of funds of knowledge because it centers community activities and practices; e.g., in terms of 'cultural communities' that sustain, evolve, and change through the dynamic interplay and intergenerational coordination of commonly shared behaviors, knowledges, practices, beliefs, and traditions that emerge between individuals, groups, and institutions (Gutiérrez and Johnson 2017). One way that CRC researchers have bolstered practice-oriented and dynamic views of culture is through collaborating with local funds of knowledge experts (hereafter, knowledge experts).

For instance, in a U.S. context, Xicana scholar activist Moreno Sandoval (2019) details an experience of working with a teacher of European-descent, 'Mr. Adams', while implementing the popular Exploring Computer Science curriculum. Through exposure to diverse cultural assets and out-of-school networking opportunities, Mr. Adams was able to connect computing to localized contexts and real-life applications beyond the formal curriculum (e.g., local gardens). In their design of CRC unplugged activities, Bennett et al. (2016) explain how they collaborated with Adinkra artisans in the Ashanti Region of Ghana to run a CS professional development workshop for teachers from across disciplines. The researchers paid the artisans to design special Adinkra Computing Unplugged manipulatives and the artisans ran demos for teachers on how to use them during the workshop. Back to a U.S. context, Lachney and Yadav (2020) argue that CRC collaborations between local knowledge experts, teachers, researchers, and technologists can make broadening participation a multi-directional strategy, where CS and STEM are not just meaningful in schools

but also other locations that are important to local communities (e.g., artisan studios, barbershops, urban gardens, etc.).

Beyond studies that focus on youth (e.g., Ashcraft, Eger, and Scott 2017), there is limited research on what collaborating with local knowledge experts looks like. This limits insights into how they feel about the racial justice goal of broadening participation and the framing of their knowledges in STEM terms. A potentially unfortunate result of this silence is an implicit, if not explicit, assumption that the views of local knowledge experts on these issues are homogenous and unified. To help avoid this misconception, we focus on the design and implementation of one CRC program that sought to broaden the participation of Black girls and young women in STEM education. It began with collaborations between researchers, technologists, teachers, high school students, and Black hairstylists, but later extended to natural cosmetic entrepreneurs, urban farmers, and librarians.

Background and methods

Background

Since 2017, we have been collaborating with Black and African American cosmetologists in the design of CRC tools and experiences that connect computing to the scientific knowledge – often related to chemistry, anatomy, and physiology – that they use in their daily practices. We decided to focus on cosmetology and hairstyling as sites for exploring funds of knowledge in STEM education because the skills of working with hair and skin often start at home within the educative social worlds of family and friend networks. They can then be extended to professional outlets of wealth generation, such as salons, braiding shops, and cosmetic businesses (Byrd and Tharps 2014). What is more, Black beauticians have a long history of playing important roles in political organizing and social change (Gill 2010; Russell 2011).

It is, therefore, not surprising that scholars have identified Black hair salons as rich sites of teaching and learning. For example, Majors (2015) explains how 'Shoptalk' – a genre of conversational discourse that is situated within the epistemic repertoires and cultural communities of African American hair salons – supports collective processes of problem-solving and meaning-making that can be relevant to teaching African American children in schools. Similarly, Emdin (2016) describes how Black barbers and hairstylists have culturally situated pedagogic expertise that teachers and pre-service teachers can learn from in their efforts to engage Black children in meaningful classroom experiences. We also build on the rich epistemic contexts of Black hair salons, specifically exploring how STEM knowledge is embedded within these dynamic cultural systems.

During the summer of 2017, our research team hired three high school girls of color as research interns. Two of the girls we met in an after-school cosmetology program and the other learned about the opportunity through her hair salon. As interns, their goal was to identify how computing and cosmetologists' funds of knowledge might connect for educational and entrepreneurial purposes (see Figure 1). The first author (Lachney, who identifies as a White man) and forth author (Babbitt, who identifies as a White man) worked with the interns to provide examples of other CRC projects that connected computing to funds of knowledge. This included talking with the second author (Eglash, who identifies as a White man) and the third author (Bennett, who identifies as a Black woman) of this paper, who created the CRC applications known as Culturally Situated Design Tools (csdt.org). In addition, the interns conducted research on the cosmetology industry and STEM fields.

Based on their initial work, the three research interns gave a presentation to a group of researchers and technologists about the importance of pH knowledge in cosmetological practices.[1] After their presentation they agreed to work with an undergraduate CS research assistant to build and calibrate an Arduino-based pH sensor (see Figure 2). They then worked with professional cosmetologists, educators, and our research team to explore different ways to visualize pH data (see Figure 3).

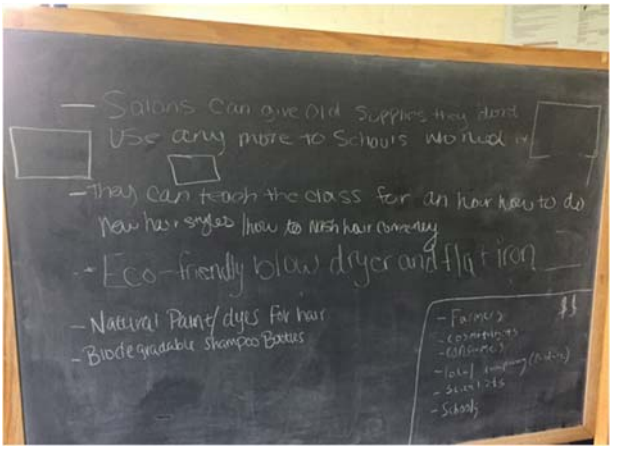

Figure 1. The three interns' brainstorming notes about how cosmetology can support STEM education, environmental sustainability, and entrepreneurship.

Figure 2. Materials from Arduino and Atlas Scientific that were used to build and calibrate the pH sensor.

With support from the research team, the interns acted as brokers between the social worlds of cosmetology, computing, and science while critiquing visual designs of the pH scale and testing out educational activities. This work eventually resulted in an online application that uses computing to connect Black hairstyling, chemistry, and entrepreneurship called pH Empowered.

We later found out that the topic of pH was partially inspired by their conversations with collaborator Lakisha Foy (fifth author, who identifies as an African American woman), who is a cosmetologist, cosmetology instructor, natural haircare expert, and natural cosmetic entrepreneur. This prompted a collaboration where Foy and two of the interns helped the research team showcase the pH Empowered application, among other educational cosmetology/science tools, at a local Black arts and culture festival (Figure 4). During this event, Foy and the interns moved between the pH Empowered booth and a stage where they showed off hairstyles and talked about hairstyling, among other topics. Instead of just seeking to situate cosmetological funds of knowledge into computing education, showcasing and demonstrating pH Empowered at the festival helped to highlight the potential benefits of also situating computing within a site where these local funds of knowledge readily circulate.

The following year Foy joined the research team to help pilot a CRC professional development workshop for cosmetologists. The goal was to see if they found the pH Empowered activities relevant to cosmetological funds of knowledge and if they enjoyed the activities enough to consider

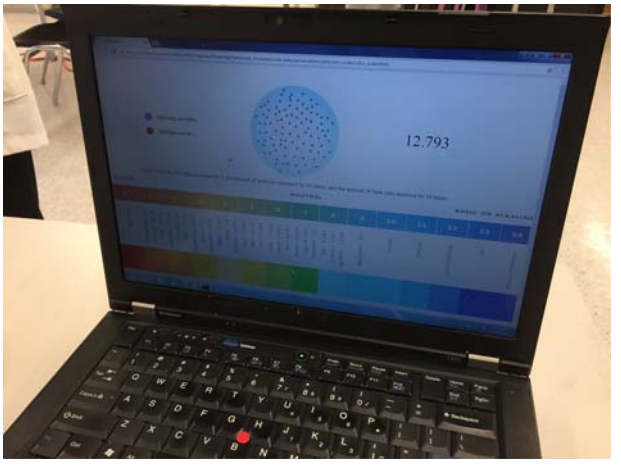

Figure 3. A digital pH visualizer, customized to support a high school cosmetology curriculum.

helping researchers, educators, and technologists implement them in school or out-of-school contexts. This workshop was made up of nine participants, all cosmetologists over the age of 18. They were recruited by Foy who worked closely with Lachney to design and run the workshop (Figure 5). Foy is well connected to cosmetologists, the beauty industry, and educational institutions around the area where we ran the workshop. She recruited participants by visiting salons and handing out flyers that included registration details. Seven of the nine participants were women and two were men. Eight participants were Black or African American and one was White.

The workshop introduced the cosmetologists to two educational technology programs that connect hairstyling and computing. The first was a culturally situated design tool called Cornrow Curves, which is a visual programming application that offers users opportunities to create designs using the adaptive scaling geometry of cornrow braids (Eglash et al. 2006; Eglash and Bennett 2009; Lachney et al. 2019). The second was pH Empowered, which includes building and calibrating pH sensors and connecting them to digital visualizers to test the pH of various off the shelf hair

Figure 4. Two high school interns demo pH Empowered at the local Black arts and culture festival.

Figure 5. Foy discusses pH and cosmetology in preparation to build, calibrate, and use pH sensors to test off the shelf hair care products.

products. This workshop helped to confirm that pH is a notable and relevant part of cosmetologists' funds of knowledge. We also found that participants were interested in using their knowledge to support education, as well as using technology and computing in their own professional practices. During the workshop, discussions ranged from cosmetologists' enjoyment about coming together for the purposes of education to skepticism about sharing their knowledge with researchers (Lachney et al. 2020). In addition, we found that the workshop participants highly valued the way that they could bridge creativity and computing with Cornrow Curves.

Since this initial professional development workshop the pH Empowered activities have been used with youth in schools, library programs, and other educational contexts across multiple U.S. states. During one of the library programs, Foy and Lachney conceptually explored the idea of growing plants in an indoor aquaponics system as ingredients for making natural cosmetics. When conducting research to see if this idea was feasible, they discovered that farmers and gardeners also require knowledge of pH for monitoring the water of aquaponics systems and, at a much broader scale, soil. Before setting up an aquaponics system in a Midwest city public library where some of the librarians were interested in fitting pH Empowered into their educational programming (which already included programs on cosmetology and gardening), we decided to use pH as a linkage between cosmetologists and urban farmers (i.e., agricultural experts who specialize in growing food and plants in city settings) in a professional development workshop. We used this opportunity to study workshop participants' attitudes about the assumptions and goals of CRC.

Workshop participants and overview

The workshop that we report on in this paper took place on a Saturday at a public library in a Midwest city over the course of six hours during January 2019. Employees from this library leveraged their own personal and professional ties with local communities of hairstylists and farmers to recruit participants. They spread information through flyers and word of mouth, connecting with people inside and outside of the library. All five members of the research team helped to facilitate the workshop, plus the sixth author (Drazin who identifies as a White man) and seventh author (Rich who identifies as a White woman), two graduate students who helped with data collection. The workshop was made up of 16 adult participants: seven cosmetologists (100% Black/African American; six women and one man), six librarians or teachers (one Black/African American, two multiracial, and three White; 100% women), and three urban farmers (one Black/African

American man, one White woman, and one White man). Their ages ranged between 17–64, with the majority above 35 years old.

The workshop was divided into four parts, with participants working individually or in pairs. First was a brief introduction to our previous work on pH Empowered and our intentions to support Black girls and young women's interest in STEM through using computing to connect Black hairstyling, chemistry, and entrepreneurship. The second part focused on building, calibrating, and debugging Arduino-based pH sensors. During the third part of the workshop they made pH 'alarms' using LEDs or speakers (Figures 6–8). Acknowledging the importance of making computing creative during the pilot workshop, the goal was to foster computational creativity by programming music or using LEDs to light up a display when sensing pH of a certain threshold. The final part of the workshop was a share-out period to reflect on the experience as one large group.

Research questions

Using data from this workshop, we sought to answer three research questions:

Figure 6. A science teacher and a librarian create a display for their LED pH alarm.

Figure 7. Two cosmetologists and a high school student show off their LED pH alarm.

Figure 8. Two urban farmers show off their LED pH alarm.

(1) How do local knowledge experts conceptualize their own funds of knowledge in STEM terms?
(2) What do local knowledge experts think about the racial justice goal of broadening participation in STEM?
(3) How might knowledge experts' insights on STEM and broadening participation shape CRC scholarship and practice?

Data collection and analysis

In our efforts to answer these questions data for this paper were collected in three ways: (1) focus group discussions with knowledge experts before and after the workshop; (2) fieldnotes and supplemental pictures taken by the research team during the workshop; and (3) a Likert-type pre/post-survey. We used a mixed-method 'triangulation design' for data collection and analysis: 'a one-phase design in which researchers implement the quantitative and qualitative methods during the same timeframe and with equal weight' (Creswell and Plano Clark 2007, 63–64). In an effort to construct valid and accurate interpretations of the workshop and its participants, we sought 'the convergence and corroboration of results from different methods and designs studying the same phenomenon' (Biesta 2017, 159).

Researchers facilitated focus group discussions before and after the workshop with three different groups of participants. This resulted in six discussions, each lasting between approximately 30–50 minutes. The groups were demarcated by workshop participants' primary areas of expertise: cosmetology, urban farming, or library/education. The discussions were transcribed and then analyzed by Lachney and Babbitt using 'provisional coding', which begins with a start list of codes generated by members of the research team based on what prior research (i.e., our pilot workshop) suggests might appear (Saldaña 2016, 297). Lachney then wrote up a narrative based on this initial analysis. This was followed by reflexive processes that involved 'dialogical intersubjectivity' (Saldaña 2016, 37) – i.e., 'agreement through a rational discourse and reciprocal criticism between those interpreting a phenomenon' (Brinkmann and Kvale 2015, 279) – where the authors synchronously and asynchronously discussed the interpretation of the data, negotiated agreements and disagreements by returning to the data and personal recollections, and/or checked that the quotes were correct and appropriately contextualized in the findings.

We also collected quantitative data with a pre/post-survey that the research team had been iteratively developing since our initial professional development workshop with cosmetologists.

Participants scored 12 statements using a five-point Likert-type scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree. The first five statements sought to measure the workshop participants' attitudes toward the relationships between science and their funds of knowledge, with a specific focus on chemistry. The next four statements aimed to measure their attitudes toward the relationships between technology and their funds of knowledge, with a specific focus on computing. The final three statements aimed to measure their attitudes toward community engagement.

Findings

Qualitative findings

Cosmetologists as STEM communicators

While some cosmetologists start off as what Foy describes as 'kitchen beauticians' – people who work out of their home, sometimes without institutional credentials – the process of obtaining a cosmetology license includes formalized education in chemistry, anatomy, and physiology. This produces unique funds of knowledge that bring together STEM and cosmetology as localized cultural systems. Indeed, cosmetologists in our workshop were very explicit about the scientific knowledge – including but not limited to pH – that they use in their professional practices. For example, one cosmetologist with over 40 years of experience explained:

> The science of the different chemicals that we use is important. We've known that, over time, different chemicals like relaxers and color, it tends to thin Black hair out. Mixing with the medications, as people, young and old, are taking more and more medications, it's tending to thin their hair out.

This quote represents how cosmetologists in our workshop tended to frame the application of their science knowledge in the salon around the lens of health. As the only man in the group of cosmetologist explained:

> There's clients that come in and have different ailments and different medicines. You got to know the chemicals that you use, how they counteract with those medicines. So that's why you sit down and have those consultations with your clients, to know what their lifestyle is. So, that's where it brings back to the science of hair.

For cosmetologists, learning about their clients through general salon talk or formal consultations is a large part of the job. Cosmetologists can spend hours with clients discussing and working on their hair, which includes using and sharing their scientific expertise.

Cosmetologists in the workshop described how they discuss science with their clients in personalized ways. For example, when Lachney followed up on their processes for communicating scientific knowledge in the salon, one cosmetologist explained: 'It just depends on the customer … It's financially, emotionally, what level the client is on. So if they want to get into the hair care of it, they'll get into the hair care, if they don't, they don't care so much'. While being responsive to their clients own level of engagement was generally agreed upon, some found it limited their ability to demonstrate and maintain their STEM expertise:

> A 45 degree cut is a layered Bob, okay, 90 degrees is just trimming the ends. Pityriasis is, that's dandruff. Trichoptilosis is dead ends. But we lose that language in the field, trying to communicate with the average person … We lose that language [because] now we're at, 'Okay girl, we just want to trim your ends … .' [group laughs] But they don't make the doctor lose their language.

This comparison to doctors reinforces the framing of their scientific expertise around healthcare. Yet, the scientific knowledge that cosmetologists have can be hidden within more vernacular language that they personalize for their clients. While this was frustrating to some workshop participants, this process of translation might be what makes cosmetologists important CRC collaborators. To articulate what they know requires understanding what their clients will be receptive to

learning about and then deciding how best to communicate that information. The idea that this could be used to support young peoples' interest in STEM was not lost on the cosmetologists.

Reflecting on the workshop, a cosmetologist explained how she might use her own position and communicative platform to support adults and children's interest in technology:

> Because we're getting that education, we're getting that knowledge, now we can sit and tell how many people? You do, what 100 people a week? You whisper that kind of technology in their ear. Okay now they can tell their child, 'look you can have a dream, you can have vision, instead of it looking like it's so far away. It's not far. It's right here.'

Indeed, while mainstream broadening participation discourses tend to assume that STEM knowledge must come from outside of racially marginalized communities, this cosmetologist knew that 'It's right here', already embedded in her own work or prompted by her own expertise. Just as CRC seeks to translate between computing and culture, cosmetologists translate the scientific into the vernacular and vice versa, acting as bridges between social worlds and domains.

Urban farmers as STEM dissidents

Similar to the cosmetologists, the urban farmers framed their STEM expertise around health, but of a more oppositional kind. While the cosmetologists sought to align themselves with mainstream science (e.g., the FDA) and medicine (e.g., nurses and doctors), the urban farmers posited their STEM expertise in opposition to extractive government and corporate institutions. They questioned government standards for what is considered healthy, critiqued the extractive practices of corporate agriculture and food systems, and articulated educational alternatives to mainstream schooling. Yet, this was not a rejection of STEM but instead a starting point for rethinking STEM's relationship to local concerns and needs.

Before the workshop, one of the White urban farmers explained the ubiquity of STEM in his field:

> So, science, technology, engineering, mathematics … I mean, all those are part of farming in some way or form. Some more on the conventional farming side. Some more on the organic farming side. But they're all involved in all aspects of farming. I mean, you got soil health, which has to do with pH and chemistry of the soil, what minerals are in there. You have technology, which makes advancements, like hoop houses are technology.

At the same time that STEM was seen as central to their profession, the farmers generally agreed that many of the ways that STEM is used to produce and sell food is 'extractive'; i.e., the depletion of resources out of a community without a generative cycle for replenishing them. Alternatively, the farmers, who already worked on out-of-school educational programs – whether developing homeschool curriculum or hosting kids at their farms or gardens – posited their project-based forms of science and health education as community-centered and generative. The other White farmer contrasted her approach to engaging youth with what she saw as the more extractive approach:

> I think a lot of the messaging that's specifically targeted at youth of color is very much extractive. It's about extracting resources from them. It's about getting people to consume products, consume food items, change the way that they think about themselves and their body in relation to food and the environment. And I think our job is to reverse that, that we're not trying to market or make a profit off of people, but we are trying to have youth understand that the food that they eat has chemical reactions inside their body and understanding the science behind nutrition, how your environment affects your health, helps people to, then, actually understand why these things matter.

This quote represents the farmers' critiques of how the corporate food industry targets youth in their community, a targeting that they saw as explicitly racialized.

It also shows how they balanced their social critiques of the dominant food system with proactive and justice-oriented alternatives. In another example, the Black farmer compared and contrasted his approach to education to more traditional approaches using food metaphors:

> So I'm teaching the education that's pretty much like a farm, a farm that's going to harvest and give us a good plate of food. You know, instead of having just a[n instant] cup of Ramen noodles education, you know? I'm trying to have a steak and potato, you know, with the whole salad, whole tall salad with the tomatoes and the cucumbers, all that in that salad on this table. You know, so it's a different level of education I want to provide.

As these quotes show, the relationships between farmers' funds of knowledge and STEM are ones of justice, dissidence, and imagination. Urban farming and gardening become direct means to create more just and sustainable futures by providing alternatives to extractive government and corporate institutions.

Librarians as community technologists

While the librarians – some who had expertise in hairstyling and gardening of their own – generally supported STEM education in their work with youth, they most readily identified their knowledge with the goal of supporting localized access to technologies. Indeed, providing access to technology and information was seen as a key service of libraries. As one of the multiracial librarians put it:

> There's all kinds of technology, little things that we do for people all the time to help them figure out how to advertise their business, or apply for a job at a business, or things that you can't do on your phone.

Throughout the discussion, the librarians saw their role as providing opportunities to use technologies that would otherwise be difficult to access. They discussed renting out items like microscopes and wifi hotspots, installing makerspaces, and providing access to DIY media production equipment.

Recognizing that broadening the use of technology and computing is more than just access, they discussed the need for libraries to support their patrons' programming and circuitry skills. One of the White librarians explained that whether for herself or library patrons, these skills need to be framed as relevant to everyday life:

> When you're talking about circuitry, it's all scientific concepts … But then when you start talking about their own home and the electricity within their own home, then it becomes something they want to learn about because it's relevant to them now.

The librarians at the workshop expressed desires or explained instances where they were able to make STEM relevant to youth and adults. But, while the library where this workshop took place did do CRC education for youth and also provided space for farmers and cosmetologists to run programs, there were no opportunities for bridging these activities. CRC that designs technologies and curricula based on localized funds of knowledge might build on the open access of libraries, as well as the technology and information literacies of librarians, to explore how to make STEM education and local sources of wealth generation (e.g., urban farms, braiding shops, etc.) more mutually supportive in broadening participation efforts.

Broadening participation and race

The cosmetologists generally agreed that their own expertise and funds of knowledge could support youths' interest in STEM. At the same time, their ideas about the underlying goal of the workshop to broaden participation by focusing specifically on Black children was less straightforward. Unlike the librarians and farmers, the topic of *race* was a substantive part of the cosmetologists' post-workshop discussion. We found that the cosmetologists had varying opinions about how explicit the role of race should be in broadening participation efforts.

The topic was prompted by one of the participants who had a concern about how race was framed at the workshop. Addressing Lachney she explained:

> I notice you put a lot of emphasis on the color. And I don't, I mean I really see you as just a person, and I want you to see me as a person … So when you say I'm reaching out to the Black [students], it cringes me because I don't understand, why the need to do that? So you're reaching out for everybody so that we can all learn. What do you got to say? Do you agree with me or no?

After some additional conversation between the cosmetologists about their personal experiences at the intersections of education, family, and racial identity, Lachney reiterated a race-conscious goal of broadening the participation of Black youth and young adults in STEM. However, this did not get to the heart of what education was about for some of the cosmetologists. In response to Lachney, another cosmetologist went on to describe a young woman who she had supported in a time of need:

> … we showed her other opportunities and got the community of the salon involved … teaching her alternatives besides focusing on, 'I'm not good enough, I'm not pretty enough, I'm not this', then she stopped. Now she's dancing, and she became a beautiful person. But that comes from education, not from color, of face, but from the prospect of who she is as an individual person. We can go on and on about color. It's not serving a purpose, at all!

For this cosmetologist and others in the workshop, the idea that CRC efforts should be explicitly focused on race seemed like a barrier to the goals of providing youth with opportunities to be individuals and work toward personalized dreams. It is not an unreasonable position: the political goals of school desegregation, for instance, rests on common and equal education opportunities regardless of race.

At the same time, this was somewhat in tension with other parts of the discussion. Reflecting on her own educational experiences, one cosmetologist explained:

> I was brought up in Alabama. I was in school when Brown versus Education. I switched schools for the White school and the Black school. So I don't see it that way, and for people to talk about the kids or whatever, it starts at home. It starts at home first. I want my kids, my daughters, I taught my daughters and my son, you Black. I see you, I don't discriminate, but you White. So that doesn't change. But, I'm going to teach my daughter to be a proud Black lady. Be proud of where you are and everything else … that's what my parents taught me. I was back in the Martin Luther King days. I saw him and everything else, went to the marches and all of that. So we was taught that.

Here, race is a historically contextualized part of individual and community empowerment in the face of and fight against anti-Black racism. In reflecting on her work with the research team, Foy discussed how a similar positive framing of racial identity might support Black children in schools:

> It makes them want to go into school and be like, you know what? I'm excited about what I'm learning today because I realize it wasn't all about slavery, it wasn't all about, you know what I am saying, the negative of me having this skin tone. It's more so about that pride and us understanding that we are a people that should be celebrated …

The anti-racist narratives that decry the violence of slavery, Jim Crow, and the prison-industrial complex must be part of U.S. schooling. At the same time, the repetition of these topics alone may also be emotionally draining for Black children. Balancing these narratives with race-positive framings offers additional ways to contest and combat White supremacy and anti-Black racism by centering the intellectual traditions, cultural expertise, and dignity of Black communities and heritages.

Quantitative findings

In addition to our qualitative data, we present Table 1 to represent changes in the mean score for each of the 12 statements from 15 matched pre/post-surveys. The workshop participant missing from our quantitative results is the Black urban farmer who only participated in the post-workshop discussion. The pre-survey mean scores all started off between 'neutral' and 'strongly agree', with each statement having some positive change on the post.

For the first five statements we sought to measure any potential changes in the participants' attitudes toward the relationship between science and their own funds of knowledge. We focused specifically on chemistry because of the importance of pH in this work. Most of the pre-survey

means were between 'agree' and 'strongly agree'. This further helped to confirm our hypothesis that chemistry content is a part of cosmetologists' localized funds of knowledge. The average for the statement, 'I feel confident talking about science to my customers or people I serve', is slightly below 'agree' on the pre-survey, but it also had the largest change from pre to post. While science is important to cosmetologists, farmers, and the librarians who host gardening and hairstyling programs, communicating that content to others is complicated (as indicated by the cosmetologists above). Using computing to explore pH in the workshop may have provided the participants with new insights about communicating their science related funds of knowledge to people without their expertise.

The next four statements aimed to measure any changes in the relationship between local funds of knowledge and technology, with a specific focus on computing. While there were less changes in the statements about confidence with and personal knowledge of technology, there were more notable changes in: 'I think that computer programming can make an important contribution to my profession' and 'I feel confident collaborating with a technology teacher to help deliver a computing lesson in the classroom.' This may suggest that workshop participants left with a more general understanding of the role that computing can play in their profession and young people's education, but were less sure that they personally had enough knowledge to make it meaningful on their own.

The final three statements aimed to measure attitudes about how the workshop participants' funds of knowledge could be used to support computing education in their local communities. The smallest changes from pre to post for the whole survey were with the statements: 'I think my profession is a source of community empowerment' and 'I feel confident explaining what computer programming is to someone younger than myself.' The former was leaning toward 'strongly agree' on both pre- and post-surveys, while the latter was between 'neutral' and 'agree', leaning toward 'agree'. We also saw the largest change in the whole survey in this area with the statement: 'I can use my expertise to help teach computing to people in my community.' When considering both the baseline scores and changes for statements in this last section, it should first be stated that perhaps the workshop participants already understood that they had important roles to play in supporting their local communities. The workshop may have helped them to see that this included computing education, but that their personal confidence with computing had not notably changed after the workshop.

Table 1. Pre/post mean scores and change from pre to post ($n = 15$).

Statement	Pre mean (sd)	Post mean (sd)	Change in mean score
I think that my profession and science can mutually support each other.	4.80 (.414)	5.00 (0)	+.20
I feel confident talking about science to my customers or people I serve.	3.93 (.883)	4.53 (.639)	+.60
I think that young people in my community would benefit from having more lessons that include my expertise in their science courses.	4.40 (.828)	4.87 (.351)	+.47
I think that understanding chemistry improves my professional practice.	4.27 (.883)	4.53 (1.125)	+.26
I would feel confident collaborating with a science teacher to help deliver a lesson about pH in the classroom.	4.27 (.883)	4.67 (.723)	+.40
I think that computer programming can make an important contribution to my profession.	4.13 (1.125)	4.73 (.457)	+.60
I feel confident using technology and computing in my practice.	3.73 (1.032)	4.00 (.845)	+.27
I feel that my customers or clients benefit from my knowledge of technology and computing.	4.20 (1.373)	4.53 (.833)	+.33
I feel confident collaborating with a technology teacher to help deliver a computing lesson in the classroom.	4.00 (1.463)	4.60 (.828)	+.60
I think my profession is a source of community empowerment.	4.80 (.414)	4.87 (.351)	+.07
I can use my expertise to help teach computing to people in my community.	3.60 (1.404)	4.40 (.910)	+.80
I feel confident explaining what computer programming is to someone younger than myself.	3.73 (1.334)	3.80 (.861)	+.07

Discussion

We have sought to provide insight into what some knowledge experts think about the underlying assumptions and goals of CRC: (1) local funds of knowledge can be incorporated into STEM education via computing; (2) doing so can support efforts to broaden the participation of racially underrepresented youth in STEM. We asked two specific questions in these regards: How do local knowledge experts conceptualize their own funds of knowledge in STEM terms? And, what do local knowledge experts think about the racial justice goal of broadening participation in STEM? By triangulating qualitative and quantitative data we provide an answer to the first question within the context of this one CRC workshop for cosmetologists, urban farmers, and librarians. We rely largely on qualitative data to answer the second question. We aim for this research to be more than just descriptive. In the process of answering these two questions we will also explore how knowledge experts' insights on STEM and broadening participation can shape CRC scholarship and practice, thus answering our third research question along the way.

How do local knowledge experts conceptualize their own funds of knowledge in STEM terms?

Our findings suggest that the farmers, cosmetologists, and librarians who we worked with saw clear connections between their own funds of knowledge and some STEM content prior to the workshop. The general agreement on statements like, 'I think that my profession and science can mutually support each other' and 'I think that computer programming can make an important contribution to my profession' for both the pre- and post-survey results support this idea. What is more, the largest change from pre to post was with the statement, 'I can use my expertise to help teach computing to people in my community.' This is an exciting indication that bridging school and community cultural systems via computing might support knowledge experts' understandings that they have valuable skills and practices for contributing to quality computing education. At the same time, many of the survey statements that spoke to confidence and personal knowledge of technology saw less change. For example, 'I feel confident explaining what computer programming is to someone younger than myself' was the lowest average on the post, with minimal change from the pre. The workshop may have supported a general understanding among workshop participants that their funds of knowledge are relevant to computing and technology in education, but that this was best supported by collaborating with technology experts, like a technology teacher or educational technology researcher. Fortunately, one goal of CRC is to foster collaborations between people with different expertise and funds of knowledge (Lachney 2017a).

The librarians identified their funds of knowledge most closely with technology, seeing it as crucial to their professional goal of making computing skills and information readily accessible to their patrons. Both cosmetologists and farmers framed their STEM expertise, largely science-based, in terms of health; e.g., the health of their clients and the health of the communities they serve. Despite these similarities, the cosmetologists and farmers differed in how they related their STEM knowledge to mainstream health and healthcare. While the cosmetologists saw themselves as being on a continuum with doctors and nurses in supporting their clients' health (e.g., 'We're near like doctors.'), the farmers positioned themselves in opposition to mainstream institutions (e.g., 'I think the American doctors are controlling the unhealthy movement.'). These different ways of relating to STEM knowledge not only came out of their own professional practices and educational backgrounds but also their methods of professional responsiveness. For the cosmetologists it was important for them to have insight into their clients' health when applying chemicals, as well as in deciding how best to approach sharing their scientific expertise with clients. For the farmers, being responsive to their community meant standing in opposition to what they saw as a bombardment of unhealthy foods and inappropriate health messaging from mainstream governmental and corporate institutions.

CRC researchers and educators might fold this knowledge back onto their own theory and practices by considering not only what funds of knowledge are relevant to STEM education but also knowledge experts' own methods for being responsive to their local conditions and contexts. In other words, CRC projects that seek to enroll local knowledge experts in educational technology design and implementation should attend to both what STEM content they use (e.g., both farmers and cosmetologists use pH) and how that knowledge is given meaning within specific socio-cultural contexts. This will provide CRC researchers and educators with opportunities to learn multiple approaches to being culturally responsive with the same STEM content, strategically deciding when to, for example, draw on oppositional discourses and when, alternatively, mainstream messaging is more appropriate.

What do local knowledge experts think about the racial justice goal of broadening participation in STEM?

While the librarians did not explicitly mention race during their discussions, they all served communities of color and some of them had been involved in computing programs that were informed by intersectionality. The farmers did bring up issues of race, specifically issues related to systemic racism and fighting against it. Race and racism were brought up when contrasting their own educational and food interventions with more mainstream ones. During a discussion about the importance of health and economics education, the Black farmer explained:

> … as a Black person experiencing growing in America, we don't get an education … so that's something I wanted to provide for, not just my peers and my cultural people, but as far as my community as well.

The farmers saw their efforts as challenging systemic racism but, unlike the cosmetologists, they did not reflect or discuss how race should be framed within the design and implementation of pH Empowered. Alternatively, the cosmetologists had a diversity of convergent and divergent perspectives on how to or how not to frame race within broadening participation efforts.

All of the cosmetologists agreed that they could play a role in supporting culturally and computationally rich STEM education. However, they differed in their opinions on if programs like pH Empowered should be designed and implemented specifically with Black children and adults in mind. At one time, some of the cosmetologists saw our emphasis on race as beyond the scope of education. In the U.S. and other places around the world where White supremacy shapes education, race can be defined deterministically, in terms of culture or biology, to homogenize people, make identities static, and justify racialized hierarchies (Vithal and Skovsmose 1997; Spring 2016). At the same time, some cosmetologists saw our emphasis on race as an opportunity to foster positive racial identities among Black children. The cultural significance of phrases like 'Black is beautiful' and 'Black power' is intimately connected to affirmations and celebrations of Black bodies and styles, including, but of course not limited to, natural hair in the form of Afros, dreadlocks, cornrows, and more (Ford 2015; Dabiri 2019).

While the pH Empowered program was designed to positively affirm Black racial identities, we think it is important to attend to the multiple meanings that race can have in the context of U.S. education during the design and implementation of CRC technologies and curricula. To do this, we should acknowledge the importance of historicizing race as a social construct that changes over time. Therefore, CRC should not only resist static and deterministic conceptions of culture (as González, Moll, and Amanti (2005) argue), but also static and deterministic conceptions of race by highlighting the dynamic, contingent, and situated histories and politics of both concepts without reducing them to each other. Hegemonic forces tend to frame race as a statistical parameter of demographics; in that regard a universalist goal of equality is all one can strive for. But for the cosmetologist who said, 'it gets very deep because I wasn't taught about me and my natural hair within cosmetology schools', the depth she references cannot be reduced to demographic parameters, but is rather about an agential network that transforms biological, cultural, and social

heritage into a creative pallet for emancipatory visions (Mercer 1987). The cosmetologists' different perspectives can help to remind CRC researchers and educators of the importance of historicizing race and racism in our work, while defining race in dynamic terms, open to multiple intersections of collective self-determination and individual self-fashioning. Fortunately, unlike other culture-based and anti-racist educational strategies, CRC prioritizes the affordances (and limitations) of computing, which, as educational technologists have long argued (e.g., Papert 1980; Resnick 2017), includes creative expression.

One way that CRC researchers and educators can learn about the potential roles of technology and computing in creative processes of racial self-fashioning and self-determination is by studying Afrofuturist art, literary, music, performance, philosophy, and social science movements (Anderson and Jones 2016). Afrofuturists from across these areas often focus on imagining and reimagining Black people's relationships to science and technology, concurrently in the past, present, and future (Nelson 2002; Gaskins 2016). These unique temporalities help to critique the existing racialized social orders and interrogate assumptions about the past during creative and artistic processes of imagining possible futures (Womack 2013). A number of artists and educational researchers have been exploring how Afrofuturism might inform the educational experiences of students of color. McGee (2020) explains that Afrofuturism provides opportunities for people of color to see themselves as part of STEM knowledge production in the past, present, and future, as well as with the tools for exposing and critiquing racism and White supremacy in STEM fields. Indeed, dominant anti-Black tendencies in U.S. education at all levels necessitate that teachers of Black children and young adults foster future-oriented modes of learning (Carey 2021).

For example, Holbert, Dando, and Correa (2020) used an Afrofuturist aesthetic framework during a program where Black teen girls critically confronted economic, environmental, and social issues through speculative and future-oriented design projects that were relevant to their own goals, families, and communities. Gaskins (2016; 2019) has explored how the 'Techno-Vernacular Creativity' practices – i.e., technological re-appropriation, innovation, and conceptual remixing – of Afrofuturists can inform strategies for supporting youths' agencies over their relationships to science and technology. Studying these examples and others can help to ensure that the race-conscious and race-positive strategies of CRC education and research include future-orientations that are focused on the expanding horizons of young people's creative expressions, critical agencies, and intellectual flourishing.

Conclusion

This paper has sought to highlight the important roles that people with localized funds of knowledge can play in CRC education. By highlighting the voices and perspectives of knowledge experts from one pH Empowered workshop, we can see that they are not unified or homogeneous in their approaches to being responsive with STEM knowledge or the framing of race in broadening participation efforts. We think these insights are important for two reasons: (1) they offer a diversity of perspectives on what being responsive with STEM looks like; (2) they reveal that race is a contested concept and race-conscious interventions should be future-oriented and supportive of creative self-fashioning and self-determination.

We also reflexively acknowledge how our findings are shaped by the identities of the workshop facilitators and discussion leaders. For example, Foy and Lachney presented the intent behind pH Empowered at the beginning of the workshop and facilitated discussions with the cosmetologists. But Lachney initially stated the research team's intention to focus on broadening the participation of Black girls and young women in STEM, acting as lead facilitator throughout the program. Lachney's identity and role may have shaped how the goal of broadening participation was perceived by the workshop participants, thus also shaping the data.

To see if CRC can foster mutually supportive relationships between funds of knowledge and STEM education in future work, we need to move beyond knowledge experts' beliefs to the design of research projects that follow them through multiple CRC collaborations with youth, teachers, and/or librarians. This will require not only collecting data on their participation in CRC programs but also on activities that are relevant to their professional knowledge and skills: does learning about computing through participating in CRC programs influence knowledge experts' professional practices? Much more work is needed, but this paper has sought to start a conversation about the crucial roles of localized knowledge experts in broadening participation in STEM and fighting against racialized computing segregation.

Note

1. In chemistry, pH stands for potential hydrogen (that is, how much hydrogen is potentially available to the reaction). Chemists operationalize pH as a measure of acidity or basicity (representing the concentration of hydrogen ions) of a substance along a scale of 0–14: 0 being extreme acidity, 7 being neutral, and 14 being extreme basicity (see Figure 3). In this study, pH acted as a type of node in a network that people with varying knowledges or different levels of expertise could work with to facilitate collaboration.

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