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Teaching in an open village: a case study on culturally responsive computing in compulsory education

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ABSTRACT

Background: As teachers work to broaden the participation of racially and ethnically underrepresented groups in computer science (CS), culturally responsive computing (CRC) becomes more pertinent to formal settings.

Objective: Yet, equity-oriented literature offers limited guidance for developing deep forms of CRC in the classroom. In response, we support the claim that "it takes a village" to develop equity-oriented CS education but additively highlight the roles of cultural experts in the process.

Methods: We use a case study methodology to explore one instance of this: a collaboration between a multi-racial team of researchers, a Black cosmetologist, and a White technology teacher.

Findings: Three themes supported the CRC collaboration: *multi-directional relationship building, iterative engagement with culture-computing*, and *collaborative implementation of a hybrid lesson*.

Implications: As opposed to orienting broadening participation around extractive metaphors like "pipelines," our case study constructs the metaphor of an "open village" to orient CS education toward collaborations between schools and the communities they serve.

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Introduction

As computer science (CS) educators in the United States work to broaden the racial, economic, gender, linguistic, disability, and neurological diversity of students in their classrooms, equitable and inclusive strategies for computing education become necessary. While acknowledging that efforts to broaden participation in CS are diverse in and of themselves (Vivian et al., 2017), this paper contributes to a heterogeneous group of efforts that focus on issues of racial equity and fit under the umbrella of *culturally responsive computing* (CRC).

CRC not only engages racially and ethnically underrepresented and marginalized youth with contextually meaningful technology experiences in educational settings, but also

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uses technology to help confront the political, economic, and social conditions that produce underrepresentation and marginalization in the first place (Eglash et al., 2017). In terms of the former, CRC efforts have shown signs of success with the meaningful engagement of underrepresented students in CS, as well as specific learning outcomes across traditional and nontraditional curricula (Morales-Chicas et al., 2019). As an example of the latter, Vilchis et al. (2015) discuss a CRC program where teen girls used digital technologies (including visual programming) to educate their local communities about social issues (e.g., teen pregnancy) that impact the school environment but are often stigmatized or ignored by adults, including teachers.

The majority of CRC research tends to report on out-of-school or after-school contexts (e.g., Eglash et al 2013a; Lachney et al., 2019; Pinkard et al., 2017; Scott et al., 2015). While there is little doubt that the focus on informal learning environments is productive, especially considering the roles that schools play in reproducing inequities (Anyon, 2014; Margolis et al., 2008), we also believe that without more attention to CRC in formal contexts the current state of underrepresentation is unlikely to improve. The limited amount of research on CRC in formal settings does highlight instances of deep engagement with culture-computing connections (e.g., Sandoval, 2019), as well as instances where there can be improvement (e.g., Davis et al., 2019). In either case, one major challenge is the shallow framing of culture-computing connections (Lachney, 2017a). In addition, the current work on CS teacher professional development that includes a focus on equity-based competencies (e.g., Goode et al., 2020 ; Ryoo et al., 2015) indicates lacuna in fostering sophisticated understandings of culture-computing connections in formal contexts.

In response, we argue that collaborations with local *cultural experts* represent profound pathways for deep forms of CRC in schools. We use the term "cultural experts" to refer to individuals with a locally respected knowledge of the relationships between cultural heritages, community identities, and social activities (thus avoiding the reduction of culture to static racialized categories). Cultural experts might include elders, religious leaders, activists, mentors, culture-based entrepreneurs, artists, artisans, or others who are embedded within a community's ecosystem of histories, beliefs, values, practices, and institutions. But, what strategies exist to support teachers' collaborations with cultural experts for the purpose of CS education?

In order to begin answering this question, we explore the challenges of reproducing shallow culture-computing connections in formal classrooms. This shallowness is not merely a gap or oversight; it is caused by specific institutional arrangements and assumptions. To clarify, consider the metaphor of a CS "pipeline": it is constructed in ways that conceive of expertise residing in elite technology companies, military labs, and other locations that are distanced from public life in general and marginalized communities in particular (e.g., De Luna Navarro, 2019). This frames young people as human resources to be extracted from their local context in service of capital and the state, not necessarily their own communities and families.

To begin constructing less extractive images and practices for broadening participation in CS than those associated with pipeline metaphors, we turn toward Ryoo et al.'s (2015) claim that "it takes a village" – not only of teachers and students but policy-makers, administrators, researchers, and others – to develop equity-oriented CS education. Beyond CS, the idea and phrase of "it takes a village" has been widely used to describe communal supports for African American youth, in and out of schools (e.g., Berkel et al., 2009; Martin et al., 2010; Harper et al., 2012; Parker et al., 2020). In support of Ryoo et al.'s and others' uses of the phrase, we propose an "open village" metaphor to emphasize the roles that cultural experts can play in not only supporting deep culture-computing connections in CS classrooms but also in orienting CS education toward honoring and celebrating localized knowledges and practices.

We ground our explanation of an open CS village in a case study where a team composed of a Black cosmetologist, a White middle school technology teacher, and a multi-racial group of researchers collaborated to design and implement a CRC lesson. Specifically, each brought their unique expertise to develop an understanding of the cultural algorithms of cornrow braids, which, we argue, are worthy of as much research and investigation as any other topic in computational mathematics. We detail three strategies that made this collaboration possible: *multi-directional relationship building, iterative engagement with culture-computing*, and *collaborative implementation of a hybrid lesson.*

Background

Culturally Relevant Pedagogy and Culturally Responsive Teaching

Although the theories and practices of CRC are only a couple of decades old, they are rooted in histories of anti-racist education, including the programs of culturally relevant pedagogy (CRP; Ladson-Billings, 1994) and culturally responsive teaching (CRT; Gay, 2018). Both CRP and CRT frame young people's identities, communities, families, languages, knowledges, and heritages as dynamic pedagogical *assets* – i.e., that which is of locally defined wealth and value – that are central to their academic and socio-emotional flourishing. While this might include multicultural elements (e.g., more diverse skin colors and names of characters in textbooks), its foundation often goes much deeper to culturally situated practices, linguistic conventions, epistemologies, and other sources of "community cultural wealth" (Yosso, 2005).

Exploring the roles of teaching and learning in building up assets and wealth in communities of color becomes especially important when considering Ladson-Billings's (2006) argument about the historical, economic, sociopolitical, and moral debts that the United States owes to Black, Brown, and Indigenous peoples due to the country's racist and colonial foundations that shape present day conditions of racial segregation and stratification, barriers to wealth generation, exclusion from civic processes, health disparities, and more. The language of *debt* implies an accrued and accumulated amount of something owed over time; implicating the harm that White supremacy inflicts on people of color across generations.

Although currently repaying these massive debts may seem insurmountable to educators, it is important and just to address them in the ongoing processes of creating more equitable educational conditions and, ultimately, futures. Toward these goals, Gay (2018) makes the case that educators should resist the institutional pull toward assimilating students of color into mainstream standards, norms, and the White status quo. As opposed to assimilation, CRT and CRP aim to recognize and value individual and community differences in the processes of designing and implementing transformative and empowering education for students of color.

Culturally Responsive Computing

CRC builds on the theories and lessons from both CRT and CRP but foregrounds the additive and supportive elements of computing to address the debts owed to people of color, especially, though not exclusively, in education systems. While CRC cannot address these debts on its own – indeed no research program can – it can certainly be part of broader politically engaged efforts and movements. CRC can help to address historical debts: challenging Eurocentric curricula and assimilationist schooling through ethical computational engagements with vernacular and Indigenous knowledge systems and designs (Bennett 2016; Eglash et al., 2006; Eglash et al., 2011; Eglash et al., 2013; Kafai et al., 2014; Sandoval, 2019). CRC can help to address economic debts: directing CS education and computing power toward localized sources of wealth generation (e.g., traditional textile artisan studios) (Eglash et al., 2019; Robinson et al., 2020). CRC can help to address sociopolitical debts: using computing to help broker school-community relationships that link adults and youth to larger social movements and political processes for racial, economic, and educational justice (Lachney, 2017b; Vilchis et al., 2015). And, CRC can help to address moral debts: i.e., exploring the contradictions between, "what we know is right and what we actually do" (Ladson-Billings, 2006, p. 8); e.g., the tension between broadening participation for the sake of justice and broadening participation for the sake of further concentrating White wealth and power (Scott and Elliot, 2020). To help address these debts there is obviously a need for heterogeneity within the CRC program, but here we group it into two lines of often overlapping research: educational technology design and curriculum development.

Pinkard (1999) and Eglash et al. (2006) have led the field in the development and design of CRC educational technologies. Pinkard's (2001) "Lyric Readers," *Rappin' Reader* and *Say Say Oh Playmate*, are computational learning environments that draw on African American children's prior knowledge of rap lyrics and clap-routines, respectively, to help with literacy instruction. The strategy builds on home and neighborhood assets to bridge oral and written language. In the context of mathematics, Eglash et al.'s (2006) *culturally situated design tools* support the exploration of Indigenous mathematical systems (e.g., the logarithmic curves used to model organic growth on the textiles and stamps of the Akan people of modern day Ghana (Bennett et al., 2016)) through virtual design projects. Technology design can also be done with young people. For example, in a type of service learning CS project, Mertz and Quesenberry (2018) worked with college students to develop a website to aid a government agency in low-income housing identification, a hospital Skype cart to facilitate communication between staff and families, and so on.

The second line of CRC research focuses less on tool design (though CRC tools are sometimes included) and more on the design and implementation of CRC curricula and programs. For example, Scott and Garcia (2016) report on a library program, COMPUGIRLS, that supported computational thinking through social justice education and community-oriented research projects. They explain how the program began by identifying "the individual and collective talents of COMPUGIRLS participants and [then] use[d] their funds of knowledge as a base for nurturing their habits of mind toward undertaking techno-social activism" (Scott & Garcia, 2016, p. 67). Another curriculum-oriented program is Kafai et al.'s (2014) Ethno E-Textiles, which leveraged the open-ended design affordances of existing electronic textile technologies to connect computing to traditional crafting and textile practices in Native American art courses and summer camps. They found that the program's promotion of "design agency" – a procedural mangling of human and non-human agencies (Bennett et al., 2016) – helped students translate their interests, ideas, and identities across platforms and artifacts. Kafai et al. (2014), note, however, that such open-ended design "also runs the risk that students will continue to view community funds of knowledge, such as local indigenous knowledges, and digital computation as distinct bodies of knowledge that do not and should not connect with one another" (p. 245). As we will describe below, making explicit culture-computing connections within CS education is not trivial and requires that students have access to both computing and cultural knowledge domains in ways that highlight their dynamic similarities and differences (Lachney et al., in review; Lachney & Yadav, 2020).

Culturally Responsive Computing in Formal Education

While CRC research tends to report on out-of-school or after-school initiatives (Eglash et al., 2013a, 2020; Erete et al., 2017; Lachney et al., 2019; Pinkard et al., 2017; Scott & White, 2013), efforts to broaden participation in computing education and fields have made this body of work also relevant to formal settings. The U.S. Computer Science for All (CSforALL) movement has been particularly important for motivating researchers, teachers, and other educational stakeholders to explore more equitable forms of CS education (Vogel et al., 2017; Ryoo, 2019). From President Obama's initiative to the national network for organizing the movement, CSforAll has brought issues of diversity, equity, and inclusivity to the forefront of K-12 CS education (Goode et al., 2018). Turning toward CRC specifically, it has largely been put in contact with compulsory education through formalized curriculum and teacher professional development.

One of the more dynamic in-school curricula is called Exploring Computer Science (ECS), which affords opportunities for computational engagements that are context specific and/or culturally relevant (Ryoo et al., 2013). As designers and researchers of ECS make clear, implementing equity-oriented CS education requires that teachers not only have CS knowledge but also knowledge of the communities where schools are located and how forms of oppression (e.g., racism and colonialism) can cause ongoing harm to those communities (Goode & Ryoo, 2019; Sandoval, 2013). In one instance of ECS implementation, Sandoval (2019), an Xicana scholar activist, worked closely with "Mr. Adams", a teacher of European-descent, to explore intersections between CS and social justice across school and not-school contexts, including going to a food justice symposium and connecting curricular content to a local community garden. In this case, the culture-computing connections were grounded in a strong, non-trivial community orientation. Reporting on a different high school CS curriculum based on culturally situated design tools, Davis et al. (2019) argue that explicit strategies and resources are needed for teachers to deeply and meaningfully engage with cultural assets (local and global), otherwise teachers might avoid them all together or emphasize false dichotomies between computing and culture.

In a qualitative study of ECS teacher professional development, Goode et al. (2020) found it challenging for many White teachers to connect ideas at the intersections of computing, race, and culture to their own pedagogical practices. Scott et al. (2010) emphasize cross-expertise relationship building in their discussion of what teachers need to know for implementing CRC programs and making such connections. For example, some COMPUGIRLS programs have brought together college students from across academic disciplines and in-service teachers, with the idea that college students can fill in teachers' technology knowledge gaps and teachers can fill in graduate students' pedagogic knowledge gaps. Whether it is professional development for supporting COMPUGIRLS programs, implementing the ECS curriculum, or another equity-oriented CS initiative, it appears that being able to bridge multiple social worlds and expertise signals teachers' abilities to support deep forms of equity-oriented CS education and CRC. While many teachers will be able to do this on their own, we argue that these bridges can also be created through collaborative relationships with local cultural experts.

Teaching in an Open Village

An important innovation of ECS and other programs is the emphasis on teacher learning communities that reach beyond individual schools. This may help overcome CS teachers' feelings of isolation in their local contexts (Gretter et al., 2019; Yadav et al., 2016). Yet, Ryoo et al. (2015, p. 368) also indicate that it is not enough for CS teachers to support each other, "it takes a village" of "administrators, policy-makers, educational researchers, computer scientists, students, and parents" to develop rich and equitable CS education. While we certainly agree with the spirit of the *it takes a village* phrase, it requires more explicit elaboration to be fully useful. If it truly takes a Manhattan project of professional resources then it cannot scale; and if we merely mean the status quo then opportunities for change are limited.

The exact origins of the phrase "it takes a village" are unknown (Goldberg, 2016). In the United States, a commonly referenced print variation is from a 1981 interview with Toni Morrison in the African American women's beauty, fashion, and culture magazine, *Essence:* "I don't think two parents can raise a child. You really need the whole village. And, if you don't have it, you'd better make it" (Morrison, 1994, p. 131). We build on this by adding the qualifier of "open" to the phrase to signal the need to invite the "whole village" to contribute to CS education: it takes an open village. We argue that an *open village* can be populated with relatively modest but generative resources that have the potential to connect formal CS education to local social life. But what does this look like in practice?

Working in the field of teacher education, Emdin (2016) suggests that one way for teachers (who do not live in the communities of color that they serve) to learn about their students is by visiting locally important institutions:

> If the barbershop or salon that the teacher visits is within the neighborhood of the school or the community that the students are from, the teacher not only learns how to engage with students by observing the ways that barbers and hairdressers interact with their clients, but also has the opportunity to learn about the neighborhood, community events, and students' parents, siblings, and extended families. (p. 59)

Yet, supporting and facilitating these types of communal opportunities for teachers has not been well explored in CS education research. It is this gap in the literature that we begin to address in this paper with the metaphor of an open village.

Context and Methods

Participants and School

Below we detail a collaboration between a multi-racial team of university researchers, a middle school technology teacher (whose pseudonym is Barbra and identifies as White and female), and a cosmetologist/entrepreneur (whose pseudonym is Tracy and identifies as Black/African American and female). Starting in October 2015 and extending into February 2016, the research team worked with Barbra and Tracy to design and implement a CRC lesson for Barbra's classroom that connected cornrow braiding, geometry, and computer programming. While the programming and math parts of the lesson fit into the existing curriculum, more difficult was the authentic integration and representation of cornrow braiding. For this reason, the collaboration between Barbra and Tracy was prompted by the first author Michael Lachney (who identifies as a White man), the second author Audrey Bennett (who identifies as a Black woman), the third author Ron Eglash (who identifies as a White man), and an undergraduate research assistant.[1]

Barbra, a middle school teacher in Upstate New York, had previously worked with Lachney in university professional development programs and while implementing CS and engineering lessons after-school. They had developed a relationship based on their shared interest in educational technology and presented together at both researcher and practitioner education conferences. Barbra was a particularly good candidate for being on the team because she already grounded her classroom in project-based learning, was excited to try new approaches to teaching, found value in collaborating with people from outside the school, and had been teaching in the same school district for over two decades. During the study, the middle school where Barbra worked served approximately 650 students, with over 50% classified as Black or African American. In addition, approximately 11% of the students were classified as Hispanic or Latino; 20% were White; 8% were Asian or Native Hawaiian/Other Pacific Islander; and 3% were multiracial. Approximately 60% of the total student population was classified by the state as economically disadvantaged.

In 2009, Tracy moved from Brooklyn to the city where Barbra's school is located. At the time of this study, Tracy owned and ran a successful hair salon, specializing in both chemical treatments and natural stylings. The research team had contacted a number of cosmetologists in the city to see if they would be interested in collaborating with the research team and Barbra – who had already agreed to be part of the project – in exchange for a small stipend. It was expected that the collaborator would not only implement the lesson but also join the research team in planning and designing it. Tracy agreed to participate and greatly contributed to the project with not only expertise in braiding and cosmetology but also a rich entrepreneurial background, service in the National Guard, and a generally strong commitment to community engagement. This background meant Tracy had social and cultural capital that other members of the team lacked.

Lesson Planning and Preparation

The collaboration between Tracy, Barbra, and the researchers focused on developing a two-day (approximately 80-minute) lesson – called "Cornrow Curves: From Community to School" – to be implemented with two of Barbra's technology education classes. A main goal of the lesson was to make explicit the underlying scaling geometric patterns of cornrow braiding. This was done through both simulating braids in a visual programming environment and physical braiding on a hair mannequin. This research built on prior work of the team (i.e., Eglash, 1999; Bennett, 2003; Eglash et al., 2006) at the intersections of ethnomathematics and graphic design. In addition to fostering a school-community relationship, the work had two additional anti-racist goals.

First, the lesson was meant to situate the adaptive scaling of cornrow braiding into more general mathematical knowledge systems from across the African continent, which supports an anti-racist challenge to Eurocentrism in the history of mathematics and mathematics education. Mathematically, cornrow braiding fits into a larger body of uniquely African designs and epistemologies that predated colonialism and are characterized by their scaling geometries. Eglash (1999) provides evidence that the geometric scaling in Indigenous African designs are in many cases intentional and precise. In the case of cornrow braiding, the naming of distinct styles is one such indication: "The Yoruba name for this style is *ipako elede*, which means the nape of the neck of a boar – because the boar's bristles show a similar nonlinear scaling" (Eglash, 1999, p. 81).

Second, the lesson aimed to celebrate and honor the historical and cultural significance of Black beauticians in the United States. Black beauticians have not only been sources of local wealth generation and cultural capital, but they have also played significant political roles in organizing for racial and economic justice (Gill, 2010; Russell, 2011). At the same time, Black hair has long been a focus of anti-Black racism in the United States (Mbilishaka & Apugo, 2020). Not a year goes by without news stories about Black children being disciplined in schools because of their hair, which can "reinforce internalized oppression about the quality of natural hairstyles on people of African descent" (Morris, 2016, p. 92). There has been a growing movement in the United States to make hair discrimination illegal. As of November 2020, the Create a Respectful and Open Workplace for Natural Hair (CROWN) Act, which bans natural hair discrimination, has become law in seven states (The Crown Act, 2020)).

To make these anti-racist connections, the lesson used a visual programming application called Cornrow Curves (Figure 1) that is part of a larger online suite of culturally situated design tools. As an online application, Cornrow Curves bridges four domains: African Indigenous knowledge, African American history, computer programming, and scaling geometry. Historically, the survival of braiding practices for African Americans takes place in the context of colonization, the transatlantic slave trade, and other instantiations of White supremacist violence (Byrd & Tharps, 2014). Much of the original Indigenous knowledge system was lost, but what survived became a form of resistance to the erasure of African identity, and its rebirth as a continued domain of algorithmic innovation (Eglash & Bennett, 2009). When navigating to the Cornrow Curves application today, it begins with a "Background" section where users explore cornrows in the context of its African origins and then through the lens of African American history and culture: as

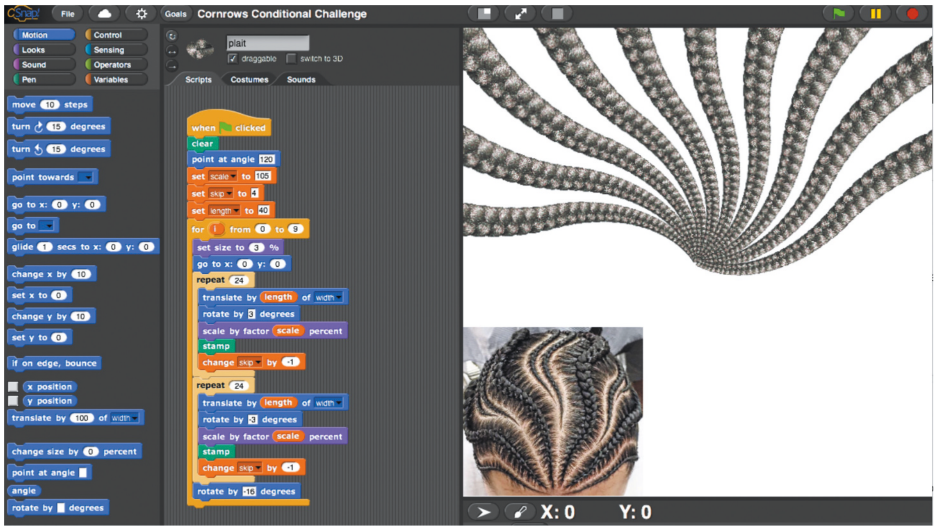

Figure 1. A cornrow curves project from the culturally situated design tool website (csdt.org).

resistance to White supremacy, as entrepreneurship during Jim Crow, and then in examples of creative applications today in hip-hop, African futurist, and Afrofuturist communities. This is followed by tutorials, challenges, and open-ended design software where users drag and drop codelet blocks to creatively study and explore the design possibilities of the beautiful geometric algorithms of cornrow braiding.

To support making these connections explicit and deep during implementation, the researchers acted as brokers between Tracy and Barbra. The team collaborated in-person and worked in an online document to create the lesson plan itself. In-person meetings and online communication were not only important for interpersonal relationship building between Tracy, Barbra, and the research team, but also for supporting each others' goals and understandings of the lesson content. Indeed, while the research team's goal was to study how a teacher and a cultural expert might support deep culture-computing connections in the classroom, Tracy and Barbra had their own reasons for participating. Tracy saw the opportunity as a way to give back to her community and Barbra saw the collaboration as a new way to support CS education.

The research team first met with Barbra to go over the Cornrow Curves application and learn about the classroom context. During this initial meeting and others, Barbra and the research team discussed the language and layout of the application and how it might be changed to fit her classroom. In particular, Barbra used her experiences with online programming tutorials to help redesign the Cornrow Curves tutorial – which was new for the research team at the time – for the age level of her classroom. Barbra spent time with the team and on her own going through each part of the application, from the background section to the software, so as to provide feedback throughout the planning process.

The research team also met with Tracy on her own. The first time was at her salon to explore the algorithms of physical braiding. During this first meeting, researchers asked Tracy to demonstrate her braiding technique on a mannequin, and Lachney tried his hand

Figure 2. Tracy and Michael explore algorithms of braiding.

to get a sense of the pattern (Figure 2). Lachney was terrible at braiding, finding it difficult to keep track of the three sections of hair (left, middle, and right) that are iteratively pulled underneath each other to create the braid. Still, this provided a way to discuss how to represent the algorithms for physical braiding and virtual braiding in ways that acknowledge their differences while still opening possibilities for contact, translation, and creative design.

During the second meeting with Tracy, the team demonstrated the Cornrow Curves software and invited Tracy to try creating some patterns of her own. Although implementing the lesson did not require Tracy to be good at using the software, it was thought that if she had knowledge of programming her participation in the classroom would be more authentic and interactive. Tracy began her visual programming education with Cornrow Curves, learning to click, drag, and drop blocks for the first time. From this meeting we learned that while the software treated each plait or twist of the hair as a single unit, Tracy also conceptualized each whole braid – made up of plaits – as a single unit. These observations led to an innovation in the software: a single "braid" block (see Figure 3) was developed that could be used to create one whole braid.

Figure 3. Current iteration of the "braid" block.

In addition to their meetings with the research team, Tracy and Barbra met on their own. The meeting was important for practical reasons because co-teaching with someone you never met increases the possibilities for miscommunication. Tracy and Barbra expressed that the meeting had two additional benefits: 1) it helped them feel more prepared and comfortable working together in Barbra's classroom and 2) it helped them feel like they were building social capital by fostering a relationship between themselves and, by extension, others beyond the immediate researcher-led collaboration.

The first day of the lesson began with a physical braiding tutorial by Tracy. She not only introduced traditional braiding techniques but also explained them using transformational geometry terms (i.e. translation, rotation, and dilation) to emphasize the adaptive scaling patterns of cornrows. This provided an introduction to the names of some of the blocks and terminology used in the Cornrow Curves application. Next, students explored the cultural, political, and historical background of cornrows on the Cornrow Curves website. Students read through the background section and then shared what they found most interesting with the rest of the class. This was followed by a opportunity to physically braid with Tracy (see Figure 4). During the second day of the lesson it was not expected for Tracy to attend – running a salon is a huge task and for cosmetologists time is money – but she showed up voluntarily. Students were reminded of what they did the previous day and were reintroduced to geometry and computing terms. They then

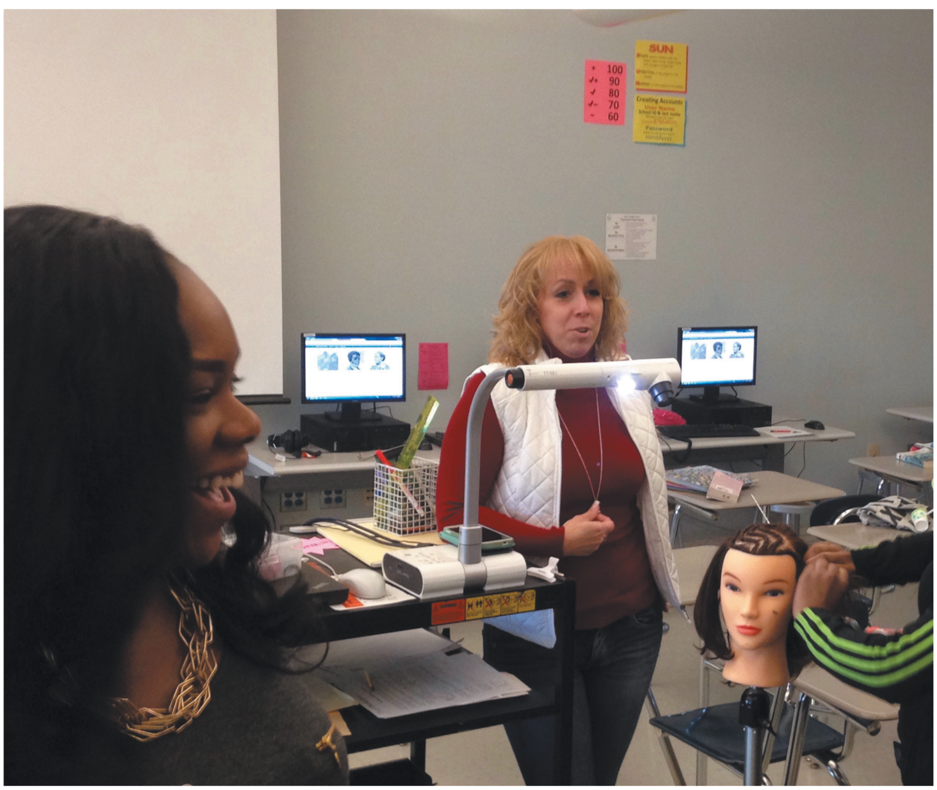

Figure 4. Tracy and Barbra talk with a student who is physically braiding during the first day of the lesson.

worked through the Cornrow Curves tutorial, learning how to program and design one braid before transitioning into the open-ended software to create designs of their own.

Methods

We used a descriptive single-case study design (Yin, 2014) to get a close-up, focused, and zoomed-in view of the collaboration between Tracy, Barbra, and the research team. One of the challenges of any case study is constructing the boundaries of the case itself, which, for us, was done around the design and implementation of the lesson plan. This methodological choice is meant to focus on revealing "patterns and connections, in relation to theoretical constructs, in order to advance theory development" (Tobin, 2010, p. 289). We are interested in advancing Ryoo et al.'s (2015) claim that it takes a village to broaden participation in formal CS education, but include in this proposition that it should be an "open" village: a village that includes diverse expertise and epistemologies beyond those traditionally associated with compulsory schooling. Therefore, an affordance of a descriptive case study is the advancement of a theoretical proposition (i.e., an open village) that can be considered beyond this particular instance.

Case studies often require the convergence of a variety of data to ensure validity and accuracy. One strategy is the process of "triangulation": comparing, corroborating, and converging multiple sources of evidence for analysis and interpretation (Yin 2014, p. 116). The term triangulation is a bit misleading, as it suggests a process with three sources. A more accurate term might be "polyangulation" because the sources of data can be as low as two and go above three (Mertler, 2019, p. 13). Commonly used sources include interviews, observations, documents, and material artifacts, but deciding what sources are appropriate is largely case dependent.

For this study, five sources of data were used to construct our findings below: the co-authored lesson plan, email correspondences between lesson plan designers, reflective semi-structured interviews with Tracy and Barbra, fieldnotes, and pictures taken by the research team during implementation. We oriented the analysis of these data around the two reflective semi-structured interviews. The interviews were conducted with Tracy and Barbra (each individually) after implementation to get their assessment of the lesson design and implementation processes. We rely heavily on these interviews in our analysis because they represent a through-line in which to connect the other data. In addition to each interview itself, we spent time together orienting the direction of the interview, catching up generally, and discussing future work. The interviews themselves lasted approximately 25-minutes. The interviews were designed around open-ended questions to prompt reflective discussion about Tracy and Barbra's experiences with Cornrow Curves, the design and implementation of the lesson plan, and their more personal and general thoughts about the whole process.

We (Lachney and Moudgalya) read the interview transcripts separately multiple times, using our own preferred methods of annotation to interpret and organize the text into themes. On two different occasions we met to systematically discuss our interpretations using a conversational technique of "dialogical intersubjectivity" (Saldaña, 2015, p. 37): "agreement through a rational discourse and reciprocal criticism between those interpreting a phenomenon" (Brinkmann & Kvale, 2015, p. 279). Given the intimate and collaborative nature of this research, we felt that this technique reinforced a methodological "closeness" (Turkle and Papert 1990; Keller, 1984) to the data that helped to conceptually simulate the lesson design and implementation processes. At the same time, Moudgalya, who was not part of the implementation, helped to construct a critical distance from the collaboration. We corroborated our interpretations with the lesson plan, emails, fieldnotes, and pictures to bolster the conversations and ensure accuracy. We interrogated and questioned our underlying assumptions at each step of the interpretive process, addressing concerns by revisiting the data and iteratively reconstructing our findings.

An Open Village Case Study

Our findings below explore three themes of the collaboration between Tracy, Barbra, and the research team: *multi-directional relationship building, iterative engagement with culture-computing*, and *collaborative implementation of a hybrid lesson*. We frame these as strategies for bringing people together in an open CS village that challenges traditional demarcations about what counts as "legitimate" knowledge in schools.

Multi-directional Relationship Building

What we mean by *multi-directional relationship building* is a sense of mutuality between those who were involved in the collaboration; i.e. the collaboration did not only benefit Barbra, her school, and the research team but also Tracy. Given that this work took place within existing institutional power dynamics, it would be wrong to assume that the reciprocity was equal or symmetrical. Therefore, we can interpret Tracy and Barbra's discussions of the project as pointing to possible ways this asymmetrical mutuality played out during the collaboration.

Let's start with Barbra and her school. At one time, Barbra explained how the lesson fit within her larger CS education goals:

> I'd like to actually do the Cornrow Curves activity again, but do Hour of Code first, and then do this activity. I think it would build a better link to this because Hour of Code does do it block by block by block and they can see it build, see the progression, where we probably could do the same thing with the Cornrow Curves.

At the same time, she also had a clear idea about how the lesson fit into her more general strategy for instructional differentiation:

> ... every activity doesn't engage every kid, so that's why I like to do a variety of activities. So when you had mentioned ... this activity, I'm like, "That'd be great" because now that hits it yet again another group of possible interest. My goal is to hopefully do something in here that engages some kid along the way. I don't expect them to be getting engaged in everything, but like the one girl who did the Cornrow Curves in third period she went right home [and] got a permission slip signed so she could come in and be in pictures.

Here, relationship building is posed to have clear implications for the implementation of Cornrow Curves and, by extension, CS education at the school. This is to be expected since everyone involved collaborated to produce a deliverable for Barbra's classroom (i.e., the lesson plan). Yet, this also highlights the risks of extracting and assimilating Tracy's localized knowledge into compulsory schooling. Indeed, shallow cultural representations that help to functionally teach CS content but do not present epistemic challenges to the mainstream curriculum or discipline can end up reproducing the White status quo (Davis et al., 2019; Lachney, 2017a).

Tracy and Barbra also used their expertise to contribute to the design of Cornrow Curves and, therefore, benefited the researchers and university. For example, Tracy had a strong influence on the creation of the "braid" block (i.e., Figure 3), which is now a main feature of the application. Here, Tracy described the process of learning to virtually simulate a cornrow design:

> It didn't take me long to do a [single] braid. But to try to do a design that I had on my mannequin head on the C-SNAP, [i.e. Cornrow Curves] that took a little mental thinking. It probably took about three hours, we were in there all day. Well, I just—I think if I were to do it now I think it'll take me like an hour.

Barbra also made contributions, especially in terms of the tutorial:

> I thought the tutorial was good, I went through it [and] was able to do the whole math one [i.e. tutorial] and then we fix[ed] the problem at the end with the color, but otherwise I thought it was easy to follow.

Each of these quotes speaks to the time and energy that Tracy and Barbra put into supporting the design of the lesson and online application, clearly directing their knowledge toward the research team.

Like K-12 school systems, universities can be extractive and assimilationist. It is extremely difficult to get beyond this messy reality while working within these systems. At the same time, it has been theorized that CRC can support "brokerage" strategies that bring together different actors and groups in dynamic coalition building for educational justice (Lachney, 2017b). Even more radical is the idea that CRC research can not only support learning but also local economic assets and activities (e.g., Black entrepreneurship, grassroots activism, artisan traditions, etc.) (Eglash et al., 2019; Robinson et al., 2020).

This is where we turn to how the collaboration may have benefited Tracy. To do this we go beyond the financial incentive from the research team, but this is not to trivialize this part of the work. Financial investments in the enrollment of cultural experts in CRC projects – paying them to participate in professional development and lesson design and implementation – should be viewed as an investment in equitable CS education. With this said, what else might Tracy have got out of the collaboration?

Tracy was explicit about what Cornrow Curves and the collaboration had to offer her and perhaps other hairstylists: "I think it gives us an opportunity to be involved with our community and get our name out there, get people coming to our salon and us helping the community as well as helping the students." Here and elsewhere, she indicated that there is inherent value in being involved and giving back to one's community. But Tracy also indicated that the collaboration around Cornrow Curves provided a type of social capital that might be turned into financial capital if putting her name "out there" results in salon customers. Indeed, both Tracy and Barbra spoke about the introductions made to other teachers in the school as a result of the collaboration. However, Tracy did not think Cornrow Curves itself could support her profession:

> C-Snap [i.e., Cornrow Curves] the program in itself, we use our hands, so unless they [i.e. the Cornrow Curves development team] can make a software for us [i.e. stylists], to be more like better in our profession . . . [it] won't help but . . . doing the project with C-SNAP and within the community does help us as stylists.

This response brings up an interesting question: how might educational technologies be designed to aid both cultural entrepreneurs and CS learners? Research in CRC technology design might take this question seriously, beginning with the design of innovative technologies for localized contexts of wealth generation (e.g., an African braiding shop, community garden, etc.) and then translating them to fit curricula and educational contexts.

While Tracy did not see any direct material benefit of the software to stylists, she did indicate that it had epistemic value. Tracy reported that participating in the project and working with Cornrow Curves provided her with not only new perspectives about math and programming but also her own expertise in braiding and her relationship to science:

> I feel like a scientist now. I could go out there [as] a scientist and a teacher, now I feel like I can just conquer the world . . . . just kidding. No, but I do—I feel like I am a lot more knowledge-able in, you know, computer programming, geometry, hair braiding.

The fact that Tracy felt that she learned additional information about braiding may indicate that the collaboration was epistemologically generative, with computing, math, and braiding working together in a co-constitutive relationship. This type of understanding is what Cornrow Curves is designed to facilitate. While the main user groups are students and teachers, exploring what cultural experts also learn from the application is worth further investigation.

Iterative Engagement with Culture-computing

Our lesson design and implementation necessitated that Tracy, Barbra, and the research team extend their material and epistemic frames of reference around cornrow braiding, math, and programmable software beyond what is traditionally expected through *iterative engagement with culture-computing*. Beyond helping to prepare for implementation, we found that collaboratively connecting braiding, math, and computing supported personal engagement with new content knowledge and reflective learning about Black cultural capital in the classroom. As we have argued throughout this paper, the purpose of working with Tracy was to challenge the risk of shallowly representing culture-computing connections. Tracy's work with the team aimed to make the connections authentic by grounding them in the local community while highlighting the fact that math and computation are part of Black culture and heritage.

In this exchange with Lachney, Tracy discussed how these connections were new for her, before reflecting on them in the context of her childhood:

> Tracy: Never, I still didn't even get it [e.g., the math connection to braiding] the first-time you guys presented it to me. It only took, like, me looking at C-SNAP [i.e. Cornrow Curves] and really understanding how it works together, where it was like, "oh I see now how it relates." And I'm like, "they should have had this a long time ago." Especially growing up in Brooklyn. Because people were not thinking about math during that time.

Michael: What were they thinking about if not math?

Tracy: Double-dutch … [laughs] I don't know, like taking the bus home. I don't know just like —you just have a different mentality when you come from urban life, when you come from like lower-income families, the ghetto, you just—you're not thinking about that, math is not important to you. It's more like survival almost. Who's going to be home when you're coming home like—or if you probably have a ton of chores, you probably have to walk home … So you're not really thinking about doing homework and—or learning math.

At one time, this exchange reinforces the claim that computing can help people of all ages think mathematically by bridging and problematizing the dichotomies between the "concrete" and "abstract" (Papert, 1980) or "physical" and "psychological" (Turkle, 1984). Indeed, Cornrow Curves aims to make explicit the mathematical sophistication of African epistemologies in the design of cornrow braids.

At the same time, it helps to show that simply adding culture to math or computing curriculum and stirring is not enough for making deep culture-computing connections. To work, the intervention needed to change the contours of the hegemonic epistemological and expertise landscape. Tracy noted that once having worked with Cornrow Curves herself, she could now see the concept of Indigenous mathematical knowledge and how an awareness of its existence might benefit Black communities. The contrast of this new awareness with Tracy's initial reaction – that there is no heritage math in her community – helps to reveal the ways that schools demarcate what is considered legitimate (e.-g.,"homework") and not-legitimate (e.g., "double-dutch") sources of mathematical knowledge.

We believe that this pattern perpetuates structural racism by discouraging access to mathematical and computational ideas that are embedded in local community contexts. When only elite cultural capital provides wealth access, a caste-like economic split results (Bourdieu, 1979). Consider, for example, the title of Hofstadter's breakthrough work linking computing and culture: *Gödel, Escher, Bach*. Couldn't it be *Gödel, Escher, Blakey*? Must neuroscience link intelligence and music as *The Mozart Effect* and not *The Marley Effect?* Does machine learning have to call its rule-based decision trees *The Cubist Model* simply because referencing Picasso fits within existing Eurocentric narratives more so than the African art works that inspired him? Such choices are ignoring the rich mathematical and computational connections to Black culture and heritage (Powell & Frankenstein eds. 1997; Eglash, 1999; Gerdes, 1999; Zaslavsky, 1999), while highlighting those of White culture. This is much to the detriment of young Black children who may be wealthy in cultural capital that is mathematically and computationally sophisticated but lack the financial means to explore math and computing by hegemonic technological framings and access.

Through her work with Tracy and the research team, Barbra also recognized the larger role that culture-computing connections can play at her school to celebrate the mathematical and computational heritages of Black peoples. She reflected that the whole implementation could be improved with more time spent on the cultural and historical background sections, as well as studying the math and computing of physical braiding processes. More so than the programming aspect, these were the unique contributions that the lesson brought to Barbra's classroom. Barbra was particularly interested in how other culturally situated design tools might fit into existing programs at her school.

After reviewing the different options, she proposed using the Adinkra Computing application – designed for users to explore how Ghanaian Adinkra artisans use logarithmic curves to model organic growth – to make t-shirts for the following year's Black History Month celebration:

> That's the other thing I like, that each of the symbols has a different meaning. So the kids can pick the ones that are of value to them. And if we were to do that for a Black History Month that means my group in the fall, I have kids fall and spring, the group in the fall will have done it, the group in the spring will have done it. I don't know, [we could] make it bigger if I get somebody [to] donate t-shirts.

Indeed, the following year Barbra did implement a Adinkra Computing lesson, connecting her classroom with the research team and a local Black historian who had intimate knowledge of the history and use of Adinkra symbols in the United States. Tracy also continued to work with the research team after the lesson, not only attending professional development workshops but also helping to connect math, computing, and braiding at a youth summer camp. The continued collaborations with Tracy and Barbra suggest that while culture-computing connections may not initially be obvious, once teachers and cultural experts have opportunities for iterative engagement with them it becomes possible to more deeply explore the connections and/or identify others.

Collaborative Implementation of a Hybrid Lesson

Here the *collaborative implementation of a hybrid lesson* pertains to the use of the final deliverable (i.e. the "Cornrow Curves: From Community to School" lesson) with students. We use the term *hybrid* to remind readers that the translation process is always messy and incomplete, but it is possible to make adjustments on both sides that ultimately provides students with ways to connect these knowledge systems and social worlds in one learning environment. When reflecting on the implementation, we found that Barbra and Tracy emphasized nontraditional expectations about expertise and authority in the classroom, which helped to center Black cultural capital.

In her pedagogy generally and in this lesson specifically, Barbra sought out and encouraged nontraditional forms of authority and a multiplicity of expertise in her classroom. For example, in addition to opening space for Tracy and the research team to help teach about braiding, math, and computing, Barbra also encouraged adults from all over the building to attend her class and show off their braiding and/or computing skills. Indeed, staff from other parts of the school did show up to the first day of the lesson, curious about the lesson and, in some cases, ready to demonstrate their own expertise. This made the classroom environment busy, active, and loud with children and adults engaged in individual or small group activities.

While she was reflecting on what could have been improved in the lesson, Barbra was able to frame her ignorance of the physical braiding process as a potential pedagogical asset for broadening who has expert knowledge and authority in her classroom:

> I'm not sure how to braid, so I wouldn't really be an asset in that. But then, now that I say that out loud, the kids that do know how to braid could be the teachers, which I think is a great thing too when the kids can go through and instruct.

This is not to suggest that Barbra reveled in her ignorance. As we have articulated above, she was committed to learning the historical, cultural, mathematical, and computational significance of cornrows. This is instead to acknowledge Barbra's ability to give up some classroom authority. Indeed, as Barbra and the research team collaborated time and time again, Barbra would pedagogically favor the active and messy classroom over a static and orderly one, which was helpful for the research team members who were committed to the design and study of bottom-up CS education.

While reflecting on lesson implementation, Tracy also recognized the affordances of letting students be the experts in the room:

> I like the students that are shy because I feel like those are the ones that really do need the help but they don't know how to express themselves. And when one of the students was shy and she didn't want—but she knew how to braid and she didn't want to show everyone that she knew how to braid. She was the one that actually had problems with the math. So having her come up and show everyone how to braid was really nice. And then when I started asking her questions on like what is this called rotation or translation or whatever and just getting her into the geometry terms and she—at first didn't remember but then when I explained it to her with the cornrow, then she remembered. And then I forgot and asked her and she reminded me.

Tracy's ability to translate knowledge across math, computing, and braiding appeared meaningful to some students. Crucially, this influenced some students' perceptions of who to ask for help from when programming in Cornrow Curves. Reflecting on her experience during the second day of the lesson Tracy explained:

> It was exciting … only because they—the students were actually coming to me to help them use it [i.e., Cornrow Curves] and I didn't expect that. I thought that they would go to you know, you guys the professionals, because you are the ones that are hosting the program. [Or] the teacher, because the teacher knows—that's their teacher, that's who they're comfortable with. So when I started to get questions and when they started to ask, like get my attention, to come over there to help them with things, I was like, "oh, like this is huge … I better remember this stuff."

This speaks to the importance of relationship building for not only supporting physical and conceptual contact between the different domains in the classroom, but also for broadening conventional understandings of computing expertise and who has relevant knowledge to CS and mathematics.

Discussion

In this paper, we have sought to support the claim that "it takes a village" to design equity-oriented CS education (Ryoo et al., 2015). The task cannot be left to teachers and students alone, but must involve relationships between a diversity of educational stakeholders, from researchers to parents and beyond. To highlight the importance of CRC for supporting racial equity in CS education, we have argued that it is helpful to think of the village as "open" to not only traditional educational stakeholders but also local cultural experts and other community members who can help teachers make deep culture-computing connections in their classrooms. But, what strategies exist to support teachers' collaborations with cultural experts for the purpose of CS education?

To begin answering this question, consider the assets that were put into contact in the case study. Tracy, Barbra, and the university researchers' collaboration was centered around Cornrow Curves itself. The software acted as a type of meeting point for CS curriculum and local cultural knowledge to connect and interact conceptually and materially. But, even when CRC software is included in CS lessons it does not guarantee deep culture-computing connections will be made (Davis et al., 2019). Indeed, Kafai et al. (2014), Goode et al. (2020), and Lachney (2017a) have made apparent that there are always risks of reproducing shallow culture-computing connections or assimilationist logics in CS education. This is why we need the open village metaphor to think through the relationships that technologies like Cornrow Curves can foster.

The collaboration between Barbra, Tracy, and the research team helped us to explore the open village metaphor, which, we argue, frames local people and their social, technical, and epistemic assets in more generative terms than the traditional pipeline metaphors that circulate CS education discourses. Reminiscent of oil pipelines, the metaphors are ultimately those of extraction, linearly moving resources across locations for processing, distribution, and consumption. In turn, these metaphors reproduce the very logics of underrepresentation that they seek to challenge: for students to be CS experts they must look and move outside of their communities that, supposedly, lack relevant knowledge.

Alternatively, our open village approach to CRC locates math and computing within local communities and knowledge systems. For example, in this paper we treated cornrow braiding as a culturally situated and complex algorithm that is worthy of as much research and investigation as any other topic in computational mathematics. Through our case study, we showed how to identify the computation of localized cultural practices, work to avoid shallow uses of culture in the classroom, and create space for local cultural experts like Tracy to shape CRC research and pedagogy. With this in mind, we think it is important to aspire to a humble but open village that is populated with relatively modest but highly generative resources, without losing the possibilities for collaborations with universities and other institutions.

Next, consider what strategies are available for these types of collaborations. We have seen how Mertz and Quesenberry (2018) used social concerns, problems, and challenges to support CS service learning opportunities. However, this strategy frames the community side only in terms of problems: the recipients of charity, not as bearers of knowledge. It also tends to focus on already-established institutions: government housing programs and hospitals have strong social value, but they may not be visions for social change. Alternatively, Sandoval (2019) and Emdin (2016) do focus on local knowledge in education and provide visions for social change: rethinking Indigenous agroecology as urban food sources and recasting rap's relationship to science in authentic inner city contexts, respectively. What makes Sandoval's and Emdin's scholarship, activism, and pedagogies transformative is not only their abilities to create deep culture-computing or culture-science connections but also that they have authentic relationships to the groups whose knowledges they are representing. But this intersection of expertise can be highly situated. The average CS teacher cannot break out computing rap lyrics, for example, with the level of required expertise for it to be meaningful and authentic.

Thus, our main focus in this paper has been a third approach where teachers and local cultural experts collaborate to create deep culture-computing connections in formal classrooms. This has been explored through the collaboration between the research team, Tracy, and Barbra. We found that this collaboration was supported by three strategies:

(1) *Multi-directional relationship building* – While the mutuality was asymmetrical, the team sought opportunities for all parties to find value in the CRC collaboration.
(2) *Iterative engagement with culture-computing* – While culture-computing connections might not be clear in the beginning of the collaboration, working to understand them through repeated interactions across contexts and media create possibilities for going deeper into the connections, making new connections, and/or identifying others.
(3) *Collaborative implementation of a hybrid lesson* – Representing multiple expertise and epistemologies in the classroom can help to challenge traditional expectations about classroom authority and diversifies whose knowledge is relevant to CS.

This is not to say that this path will always be the best, but we believe it is often an overlooked possibility that needs to be better highlighted and researched.

To help other researchers and educators think about this approach– moving from an orientation of pipelines to an orientation of villages – we offer the following list of questions to be critically considered within the context of a project's local power dynamics.

(1) Do math/computing connections emerge from and are motivated by cultural materials?
(2) Is the math/computing sophistication located in practitioners' heads, hearts, and hands?
(3) Does the representation of the cultural components attend to the histories and politics of power?
(4) Is the selection of artifacts made with respect to students' interests, histories, and expanded horizons?

By prompting ourselves and others to ask these questions, we can aim to ethically bring knowledge systems into contact – in an open village – without smoothing over their differences or reducing them to each other.

Limitations

While our methodological choice of a descriptive single-case study opens up space for theoretical innovation, it is also limited by forgoing a certain level of generalizability. This is not necessarily a deficit but can be framed as an asset. As its name suggests, CRC aims to be responsive to the particularities of local contexts. The shape, terms, and conditions of any CRC collaboration need to be determined on a case-by-case basis by those parties involved. It may be that the strategies for the collaboration that were detailed in this paper do not work for others.

What is more, it may be that there are instances where it is inappropriate to bring cultural knowledges, artifacts, designs, or practices into contact with CS or compulsory education, especially if they are sacred to a particular community and should not be shared with people from outside. As a way to mitigate the potential harm that compulsory education can do to people and knowledge systems, we advocate for providing clear opportunities for cultural experts to refuse the use of their knowledges in the classroom or to exit the project altogether (see Lachney et al., 2020; Tuck & Yang, 2014).

Future Work

Our findings show that one of the biggest challenges for the research team was directing value back to Tracy and her salon. Designing and researching technologies that are useful in both school and professional contexts might help CRC researchers and technologists think through this challenge. Indeed, a generative approach to educational technology might begin with design challenges faced by people who are wealth generators in the local community. Working with cosmetologists specifically, we have learned that many want to find a way to measure the strength of individual strands of hair. With this in mind, we have started to design systems that use weights and gage springs to measure the strength of individual strands, while also exploring how this might support an engineering lesson on the topic of tensile strength in high school cosmetology education.

Our findings also suggest that when cultural experts have programming skills they can help students challenge traditional assumptions about who has relevant knowledge to computing. Indeed, we thought it was notable that students in Barbra's class not only looked to Tracy for braiding knowledge but also programming and math knowledge. Yet, we have found that many cultural experts are non-programmers and there is little research on supporting their programming skills. Future research must focus on how to appropriately and responsively support cultural experts' programming skills during CRC collaborations.

Conclusion

Broadening participation discourses have often used pipeline metaphors, but we believe it is now time to find new ones that better align with visions of social justice and racial equity. Indeed, there is evidence to suggest that racially underrepresented and minoritized students can be motivated to persist in STEM education when room is made in curricula for commitments to equity and justice (McGee & Bentley, 2017; McGee, 2020). However, in the United States context, piping and pipelines can conjure up images of encroachments on Indigenous sovereignty (e.g., the Standing Rock Sioux Tribe's fight against the Dakota Access Pipeline) (Estes, 2019) and environmental racism (e.g., the leaching of lead from old pipes into Flint's water supply) (Michigan Civil Rights Commission, 2017). Why put trust in another pipeline?

While these images might motivate people to work toward social change, they certainly do not make one want to be *in* or *part* of a pipeline. Not only might technocratic pipeline metaphors be off-putting to some Black, Brown, and Indigenous communities, but the metaphors ultimately frame young people as human capital to be extracted from their local contexts and put in service of the state and/or corporations. Could it be that this reproduces logics of underrepresentation? We thinks so! The implicit, if not explicit, message that pipeline metaphors send to young people is that if they want to deeply engage with computing they must look outside of their own communities that supposedly lack relevant expertise and knowledge.

As an alternative to this deficit framing of young people and their communities, we think Ryoo et al.'s (2015) use of the phrase "it takes a village" to describe equity-oriented CS education is much more appropriate, and represents a communal spirit of teaching and learning that is consistent with the values of many communities who are underrepresented in CS. Building on Morrison's (1994) variation of the phrase, we have sought to show how the metaphor of an *open village* can help us to think about the roles of cultural and community experts in making CS education more equitable. Grounded in CRC, this paper has sought to explore strategies for fostering collaborations between cultural experts, teachers, and researchers. We think that doing so can help to challenge hegemonic assumptions about the relationships between culture and computing. Join us in reconceptualizing broadening participation in CS by moving from a focus on pipelines to a focus on villages.

Note

1. The other two authors of this paper, Aman Yadav (who identifies as an Indian man) and Sukanya Moudgalya (who identifies as an Indian woman), were not part of the research team at the time.

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References

Anyon, J. (2014). *Radical possibilities: Public policy, urban education, and a new social movement*. Routledge.

Bennett, A. (2003). Towards an autochthonic black aesthetic for graphic design pedagogy. *Journal of Design Research*, *3*(2), 61–70. doi:10.1504/JDR.2003.009832.

Bennett, A., Eglash, R., Lachney, M., & Babbitt, W. (2016). Design agency: Diversifying computer science at the intersections of creativity and culture. In M. Raisinghan (Ed.), *Revolutionizing education through web-based instruction* (pp. 35–56). IGI Global.

Bennett, A. G. (2016). Ethnocomputational creativity in steam education: A cultural framework for generative justice. *Teknokultura*, *13*(2), 587–612. https://doi.org/10.5209/rev_TEKN.2016.v13.n2.52843

Berkel, C., Murry, V. M., Hurt, T. R., Chen, Y. F., Brody, G. H., Simons, R. L., ... & Gibbons, F. X. (2009). It takes a village: Protecting rural African American youth in the context of racism. *Journal of Youth and Adolescence*, *38*(2), 175–188.

Bourdieu, P. (1979). *Distinction: A social critique of the judgement of taste*. Harvard University Press.

Brinkmann, S., & Kvale, S. (2015). *InterViews: Learning the Craft of Qualitative Research Interviewin*. Sage.

Byrd, A., & Tharps, L. (2014). *Hair story: Untangling the roots of black hair in America*. Macmillan.

Davis, J., Lachney, M., Zatz, Z., Babbitt, W., & Eglash, R. (2019, February). A cultural computing curriculum. *In Proceedings of the 50th ACM Technical Symposium on Computer Science Education* (pp. 1171–1175). Minneapolis, MN, USA: ACM.

De Luna Navarro, J. (2019). *How Fossil Fuels Pollute STEM Education*. Institute for Policy Studies. Accessed May 11 2020. https://ips-dc.org/how-fossil-fuels-pollute-stem-education/

Eglash, R. (1999). *African fractals: Modern computing and indigenous design*. Rutgers University Press.

Eglash, R., Babbitt, W., Bennett, A., Bennett, K., Callahan, B., Davis, J., . . . Tully, K. (2017). Culturally situated design tools: Generative justice as a foundation for STEM diversity. In J. Thomas & Y. Rankin (Eds.), *Moving students of color from consumers to producers of technology* (pp. 132–151). IGI Global.

Eglash, R., & Bennett, A. (2009). Teaching with hidden capital: Agency in children's computational explorations of cornrow hairstyles. *Children Youth and Environments*, *19*(1), 58–73.

Eglash, R., Bennett, A., O'Donnell, C., Jennings, S., & Cintorino, M. (2006). Culturally situated design tools: Ethnocomputing from field site to classroom. *American Anthropologist*, *108*(2), 347–362. https://doi.org/10.1525/aa.2006.108.2.347

Eglash, R., Gilbert, J. E., & Foster, E. (2013). Toward culturally responsive computing education. *Communications of the ACM*, *56*(7), 33–36. https://doi.org/10.1145/2483852.2483864

Eglash, R., Gilbert, J. E., Taylor, V., & Geier, S. R. (2013a). Culturally responsive computing in urban, after-school contexts: Two approaches. *Urban Education*, *48*(5), 629–656. https://doi.org/10.1177/0042085913499211

Eglash, R., Krishnamoorthy, M., Sanchez, J., & Woodbridge, A. (2011). Fractal simulations of african design in pre-college computing education. *ACM Transactions on Computing Education (TOCE)*, *11*(3), 17. https://doi.org/10.1145/2037276.2037281

Eglash, R., Lachney, M., Babbitt, W., Bennett, A., Reinhardt, M., & Davis, J. (2020). Decolonizing education with Anishinaabe arcs: Generative STEM as a path to indigenous futurity. *Educational Technology Research and Development*, *68*(3), 1569–1593 https://doi.org/10.1007/s11423-019-09728-6.

Eglash, R., Robert, L., Bennett, A., Robinson, K. P., Lachney, M., & Babbitt, W. (2019). Automation for the artisanal economy: Enhancing the economic and environmental sustainability of crafting professions with human–machine collaboration. *Ai & Society*, 1–15. https://doi.org/10.1007/s00146-019-00915-w

Emdin, C. (2016). *For white folks who teach in the hood .. and the test of y'all too: Reality pedagogy and urban education*. Beacon Press.

Erete, S., Martin, C. K., & Pinkard, N. .(2017). Digital youth divas: A program model for increasing knowledge, confidence, and perceptions of fit in STEM amongst black and brown middle school girls, In Y. Rankin & J. Thomas (Eds.), *Moving Students of Color from Consumers to Producers of Technology*. (pp. 152–173). IGI Global

Estes, N. (2019). Standing Rock versus the Dakota access pipeline, and the long tradition of indigenous resistance. Verso.

Gay, G. (2018). *Culturally responsive teaching: theory, research, and practice*. Teachers College Press.

Gerdes, P. (1999). *Geometry from Africa: Mathematical and educational explorations*. MAA Press.

Gill, T. M. (2010). *Beauty shop politics: African american women's activism in the beauty industry*. University of Illinois Press.

Goldberg, J. (2016). It takes a village to determine the origins of an african proverb. goats and soda: stories of life in a changing world. *National public radio*. Accessed November. 17th 2020. NPR. https://www.npr.org/sections/goatsandsoda/2016/07/30/487925796/it-takes-a-village-to-determine-the-origins-of-an-african-proverb

Goode, J., & Ryoo, J. J. (2019). Teacher knowledge for inclusive computer learning. In S. A. Fincher & A. V. Robins (Eds.), *The Cambridge handbook of computing education research* (pp. 709–726). Cambridge University Press.

Goode, J., Flapan, J., & Margolis, J.(2018). Computer science for all: A school reform framework for broadening participation in computer science. In Tierney, W, Corwin, Z., & Ochsner, A. (Eds). *Digital equity and educational opportunity*. (pp. 45–65). Baltimore, MA: John Hopkins Press.

Goode, J., Johnson, S. R., & Sundstrom, K. (2020). Disrupting colorblind teacher education in computer science. *Professional Development in Education*, *46*(2), 354–367. doi:10.1080/19415257.2018.1550102.

Gretter, S., Yadav, A., Sands, P., & Hambrusch, S. (2019). Equitable learning environments in K-12 computing: Teachers' views on barriers to diversity. *ACM Transactions on Computing Education*, *19*(3), 1–16. https://doi.org/10.1145/3282939

Harper, G. W., Timmons, A., Motley, D. N., Tyler, D. H., Catania, J. A., Boyer, C. B., & Dolcini, M. M. (2012). "It takes a village:" Familial messages regarding dating among African American adolescents. *Research in Human Development*, *9*(1), 29–53. doi:10.1080/15427609.2012.654431.

Kafai, Y., Searle, K., Martinez, C., & Brayboy, B. (2014, March). Ethnocomputing with electronic textiles: culturally responsive open design to broaden participation in computing in american indian youth and communities. *In Proceedings of the 45th ACM Technical Symposium on Computer Science Education* (pp. 241–246). Atlanta, GA: ACM.

Keller, E. F. (1984). *A feeling for the organism, 10th anniversary edition: The life and work of Barbara McClintock*. Macmillan.

Lachney, M., Green, B., Allen., M., & Foy, L. (in review). Ethnocomputing and Computational thinking. A. Yadav & U. D. Berthelsen Eds., Computational Thinking in Compulsory Education. *A Pedagogical Perspective*. Routledge.

Lachney, M. (2017a). Computational communities: African-american cultural capital in computer science education. *Computer Science Education*, *27*(3–4), 175–196. https://doi.org/10.1080/08993408.2018.1429062

Lachney, M. (2017b). Culturally responsive computing as brokerage: Toward asset building with education-based social movements. *Learning, Media and Technology*, *42*(4), 420–439. https://doi.org/10.1080/17439884.2016.1211679

Lachney, M., Babbitt, W., Bennett, A., & Eglash, R. (2019). Generative computing: African-american cosmetology as a link between computing education and community wealth. *Interactive Learning Environments*, 1–21. https://doi.org/10.1080/10494820.2019.1636087

Lachney, M., Babbitt, W., Bennett, A., & Eglash, R. (2020). "A Voice to Talk About it": Cosmetologists as STEM experts in educational technology design and implementation. *European Journal of Open, Distance and E-learning*, *22*(2), 41–55. https://doi.org/10.2478/eurodl-2019-0009

Lachney, M., & Yadav, A. (2020). Computing and community in formal education. *Communications of the ACM*, *63*(3), 18–21. https://doi.org/10.1145/3379918

Ladson-Billings, G. (1994). *The dreamkeepers: Successful teachers of African American children*. Jossey-Bass.

Ladson-Billings, G. (2006). From the achievement gap to the education debt: Understanding achievement in U.S. schools. *Educational Researcher*, *35*(7), 3–12. https://doi.org/10.3102/0013189X035007003

Margolis, J., Holme, J., Estrella, R., Goode, J., & Nao, K. (2008). *Stuck in the Shallow End: Education, Race, and Computing*. MIT Press.

Martin, B., Harrison, C., & Bukstein, S. (2010). " It takes a village„ for African American male scholar-athletes. *Journal for the Study of Sports and Athletes in Education*, *4*(3), 277–295. doi:10.1179/ssa.2010.4.3.277.

Mbilishaka, A. M., & Apugo, D. (2020). Brushed aside: African american women's narratives of hair bias in school. *Race Ethnicity and Education*, 1–20. https://doi.org/10.1080/13613324.2020.1718075

McGee, E. O. (2020). *Black, Brown, Bruised: How Racialized STEM Education Stifles Innovation*. Harvard University Press.

McGee, E. O., & Bentley, L. (2017). The equity ethic: Black and latinx college students reengineering their STEM careers toward justice. *American Journal of Education*, *124*(1), 1–36. https://doi.org/10.1086/693954

Mertler, C. A. (2019). *Action Research: Improving Schools and Empowering Educators*. SAGE Publications.

Mertz, J., & Quesenberry, J. (2018, November). A scalable model of community-based experiential learning through courses and international projects. In 2018 *World Engineering Education Forum-Global Engineering Deans Council (WEEF-GEDC)* (1–6). Albuquerque, NM: IEEE.

Michigan Commission on Civil Rights. (2017). *Flint water crisis: Systemic racism through the lens of flint*. The Michigan Department of Civil Rights. Accessed Nov. 24, 2020. https://www.michigan.gov/documents/mdcr/VFlintCrisisRep-F-Edited3-13-17_554317_7.pdf

Morales-Chicas, J., Castillo, M., Bernal, I., Ramos, P., & Guzman, B. (2019). Computing with relevance and purpose: A review of culturally relevant education in computing. *International Journal of Multicultural Education*, *21*(1), 125–155. https://doi.org/10.18251/ijme.v21i1.1745

Morris, M. (2016). *Pushout: The criminalization of Black girls in schools*. The New Press.

Morrison, T. (1994). *Conversations with Toni Morrison*. Univ. Press of Mississippi.

Papert, S. (1980). *Mindstorms: Computers, Children, and Powerful Ideas*. Basic Books.

Parker, J. S., Garnes, J. N., Oliver, E. D., Amabile, A., & Sarathy, A. (2020). It takes a village: Understanding African American High School students' self-determination in School. *School Psychology Review*, 1–19.

Pinkard, N. (2001). Rappin' reader and say say oh playmate : Using children's childhood songs as literacy scaffolds in computer-based learning environments. *Journal of Educational Computing Research*, *25*(1), 17–34. https://doi.org/10.2190/B3MA-X626-4XHK-ULDR

Pinkard, N., Erete, S., Martin, C. K., & McKinney de Royston, M. (2017). Digital youth divas: Exploring narrative-driven curriculum to spark middle school girls' interest in computational activities. *Journal of the Learning Sciences*, *26*(3), 477–516. https://doi.org/10.1080/10508406.2017.1307199

Pinkard, N. D. (1999). Lyric reader: An architecture for creating intrinsically motivating and culturally responsive reading environments. *Interactive Learning Environments*, *7*(1), 1–30. https://doi.org/10.1076/ilee.7.1.1.3599

Powell, A. B., & Frankenstein, M., Eds.. (1997). *Ethnomathematics: Challenging Eurocentrism in Mathematics Education*. State University of New York Press.

Robinson, K. P., Eglash, R., Bennett, A., Nandakumar, S., & Robert, L. (2020). Authente-Kente: Enabling authentication for artisanal economies with deep learning. *iAI & Society*, 1–11. https://doi.org/10.1007/s00146-020-01055-2

Russell, C. (2011). A beautician without teacher training: Bernice robinson, citizenship schools and women in the civil rights movement. *The Sixties*, *4*(1), 31–50. https://doi.org/10.1080/17541328.2011.570031

Ryoo, J., Goode, J., & Margolis, J. (2015). It takes a village: Supporting inquiry-and equity-oriented computer science pedagogy through a professional learning community. *Computer Science Education*, *25*(4), 351–370. https://doi.org/10.1080/08993408.2015.1130952

Ryoo, J. J., Margolis, J., Lee, C. H., Sandoval, C. D., & Goode, J. (2013). Democratizing computer science knowledge: Transforming the face of computer science through public high school education. *Learning, Media and Technology*, *38*(2), 161–181. https://doi.org/10.1080/17439884.2013.756514

Saldaña, J. (2015). *The Coding Manual for Qualitative Researchers*. Sage Publishing.

Sandoval, C. D. M. (2013). Critical ancestral computing: A culturally relevant computer science education. *PsychNology Journal*, *11*(1), 91–112.

Sandoval, C. D. M. (2019). *Ancestral Knowledge Meets Computer Science Education: Environmental Change in Community*. Palgrave Macmillan.

Scott, K. A., Clark, K., Hayes, E., Mruczek, C., & Sheridan, K. (2010). Culturally Relevant Computing Programs: Two Examples to Inform Teacher Professional Development. *In Society for Information Technology & Teacher Education International Conference*. 1269–1277, San Diego, CA: AACE.

Scott, K. A., & Elliott, S. (2020). STEM diversity and inclusion efforts for women of color: A critique of the new labor system. *International Journal of Gender, Science and Technology*, *11*(3), 374–382.

Scott, K. A., & Garcia, P. (2016). Techno-social change agents: fostering activist dispositions among girls of color. *Meridians*, *15*(1), 65–85. https://doi.org/10.2979/meridians.15.1.05

Scott, K. A., Sheridan, K. M., & Clark, K. (2015). Culturally responsive computing: A theory revisited. *Learning, Media and Technology*, *40*(4), 412–436. https://doi.org/10.1080/17439884.2014.924966

Scott, K. A., & White, M. A. (2013). COMPUGIRLS' Standpoint: culturally responsive computing and its effect on girls of color. *Urban Education*, *48*(5), 657–681. https://doi.org/10.1177/0042085913491219

The CrownAct. (2020). *The Official Campaign of The Crown Act*. The CROWN Coalition Accessed November 24 2020. https://www.thecrownact.com/

Tobin, R. (2010). Descriptive Case Study. In A. J. Mills, G. Durepos, & E. Wiebe (Eds.), *Encyclopedia of Case Study Research* (pp. 288–289). Sage Publishing.

Tuck, E., & Yang, K. W. (2014). R-Words: Refusing Research. In D. Paris & M. T. Winn (Eds.), *Humanizing Research: Decolonizing Qualitative Inquiry with Youth and Communities* (pp. 223–247). SAGE Publications.

Turkle, S. (1984). *The Second Self: Computers and the Human Spirit*. MIT Press.

Turkle, S., & Papert, S. (1990). Epistemological Pluralism: Styles and voices within the computer culture. signs. *Signs*: *Journal of Women in Culture and Society*, *16*(1), 128–157. https://doi.org/10.1086/494648

Valli, L., Stefanski, A., & Jacobson, R. (2016). Typologizing school–community partnerships: A framework for analysis and action. *Urban Education*, *51*(7), 719–747. https://doi.org/10.1177/0042085914549366

Vilchis, M., Scott, K., & Besaw, C. (2015). COMPUGIRLS Speak: How We Use Social Media for Social Movements. In E. Middaugh & B. Kirshner (Eds.), *#youthaction: Be coming Political in the Digital Age* (pp. 59–79). Information Age Publishing.

Vivian, R., Falkner, K., & Szabo, C. (2017, March). Broadening participation in computer science: key strategies from international findings. *In proceedings of the 2017 ACM SIGCSE technical symposium on computer science education* (697–698). Seattle, WA: ACM.

Vogel, S., Santo, R., & Ching, D. (2017, March). Visions of computer science education: Unpacking arguments for and projected impacts of cs4all initiatives. *In proceedings of the 2017 ACM SIGCSE technical symposium on computer science education* (pp. 609–614). Seattle, WA: ACM.

Yadav, A., Gretter, S., Hambrusch, S., & Sands, P. (2016). Expanding computer science education in schools: Understanding teacher experiences and challenges. *Computer Science Education*, *26*(4), 235–254. https://doi.org/10.1080/08993408.2016.1257418

Yin, R. K. (2014). *Case Study Research and Applications: Design and Methods, 5th edition*. Sage publications.

Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race Ethnicity and Education*, *8*(1), 69–91. https://doi.org/10.1080/1361332052000341006

Zaslavsky, C. (1999). *Africa Counts: Number and pattern in African Cultures*. Lawrence Hill Books.