Computer Science Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ncse20

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To cite this article: Jean J. Ryoo , Tiera Tanksley , Cynthia Estrada & Jane Margolis (2020): Take space, make space: how students use computer science to disrupt and resist marginalization in schools, Computer Science Education, DOI: 10.1080/08993408.2020.1805284

To link to this article: https://doi.org/10.1080/08993408.2020.1805284

Published online: 27 Sep 2020.

COMPUTER SCIENCE EDUCATION
https://doi.org/10.1080/08993408.2020.1805284

Routledge
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Take space, make space: how students use computer science to disrupt and resist marginalization in schools

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ABSTRACT

Background and Context: Overlaying Computer Science (CS) courses on top of inequitable schooling systems will not move us toward "CS for All." This paper prioritizes the perspectives of minoritized students enrolled in high school CS classrooms across a large, urban school district in the Western United States, to help inform how CS can truly be for all.

Objective: This paper explores what student agency looks like while answering the research question "From the perspective of minoritized students historically underrepresented in computing, what makes a critical difference in their sense of agency in introductory CS high school classes?"

Method: Our research-practice partnership used qualitative data (including classroom observations, interviews, student artifacts, and video/photos) and surveys to surface the perspectives and visions of minoritized youth.

Findings: The research describes what student agency looks like as youth – who have had no prior CS learning experiences – use CS as a tool to resist marginalization and dehumanizing school contexts, while declaring their own "rightful presence" in CS classrooms.

Implications: Findings demonstrate the importance for CS curricula and pedagogy to center the lives of students in ways that are consequential for minoritized youth. This would support deeper engagement with content learning and student agency with computing.

ARTICLE HISTORY
Received 30 October 2019
Accepted 31 July 2020

KEYWORDS
Equity; student agency; broadening participation in computing

Introduction: computer science education that reinforces or challenges the status quo?

Nearly everything we do in our daily lives – from how we communicate, buy the things we need, learn and spend time with friends during the COVID-19 pandemic, etc. – is shaped by computer science (CS). And particularly now, following the murder of George Floyd and the increased support for the Black Lives Matter movement, we are seeing how youth have been using CS tools, including social media platforms, to organize activism against white supremacy (e.g., Jason, 2018; Tanksley, 2019; Zaveri, 2020, etc.). Even Darnella

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Frazier, the brave young woman who used her cell phone to film and educate the world about George Floyd's murder, was only seventeen years old.

And while many have been using computing tools for good, the algorithms powering our technological tools that computer scientists design have also been shown to cause great harm to the young women, People of Color, and low-income communities currently using technology in the Black Lives Matter movement and beyond (Eubanks, 2018; O'Neil, 2016). For example, Noble (2018) describes how when searching the term "Black girls" on Google, the top results are all hyper-sexualized references. When entering the words "Women need to … " in a Google Search box, the autosuggestions for finishing this statement include things such as: "be put in their places, know their place, be controlled, be disciplined" (Noble, 2018, p. 15). While such search algorithms are influenced by user input over time, they are in no way neutral or value-free. As Noble (2018) explains, "[T]he political nature of search demonstrates how algorithms are a fundamental invention of computer scientists who are human beings – and code is a language full of meaning and applied in varying ways to different types of information" (p. 26). Additionally, race and technology are co-produced in ways that are deeply rooted in a capitalist system where cost and efficiency drive algorithmic designs (Benjamin, 2019a). This results in CS creations such as medical algorithms that favor white patients over sicker Black patients when using costs as a proxy for health needs (Benjamin, 2019b; Obermeyer et al., 2019).

Noble (2018) notes that one of the reasons why CS algorithms have had such deleterious impacts on minoritized populations is because the computer scientists designing these algorithms are not representative of our diverse communities that engage with CS-influenced tools on a daily basis. The CS world continues to be made up of a majority white and Asian[1] male population: the current computing workforce is only 26% female, of whom only 6% are Asian American, 3% African American, and 2% Latina (National Center for Women & Information Technology, 2019). At the university level, only 20.9% of computer science undergraduate majors are female, 26.5% Asian, 7.7% Latinx, 3.1% Black, and 0.2% American Indian or Native Alaskan (Zweben & Bizot, 2019). Of course, this is not because women and People of Color are disinterested in CS. Rather, it is because students have not had equal access to quality CS education in our public schools, with young women and Students of Color commonly being tracked out of computing classes when/if they were available at their schools (Margolis et al., 2008/2017; Oakes, 1985). If CS included more People of Color, women, and more people overall who understand how histories of colonization, slavery, and patriarchy have negatively shaped human consciousness, perhaps we wouldn't see computing algorithms reinforcing false and destructive stereotypes, racism, sexism, or heterosexism.

To address these equity issues in computing as well as the underrepresentation we see in computing fields, the CS for All movement has spread throughout the US, seeking to ensure that all students – regardless of gender, race/ethnicity, socioeconomic status, ability, home language, etc. – have access to quality CS education that encourages their interest in the field and understanding of ways to apply CS to various careers and social purposes. As we challenge the underrepresentation of minoritized communities in CS, we must ensure that students have opportunities to learn CS in school and gain a critical consciousness of the ways that computing influences our daily lives. Of course, this means teaching CS in ways that not only increase student access to CS content knowledge and skills, but that also actively examine current trends in computer science that are "misery

for some, monopoly for others . . . we can't only critique the underside, but we also have to wrestle with the deep investments that many people have for social domination" (Benjamin, 2019b). CS education should not simply thrust minoritized students toward status quo and middle-class ideas of working as uncritical programmers, but instead encourage students to utilize their diverse lived experiences and voices to ask the critical question: computing *toward what ends?* (Vakil, 2018; Vossoughi & Vakil, 2018).

Yet, as many of us have personally experienced and/or understand: such an effort is not as simple as merely bringing CS curricula or educators into schools (Goode et al., 2012, 2018; Margolis et al., 2012). Simply teaching students how to program does not necessarily motivate interest or engagement (Margolis & Fisher, 2001). The same can be said for a developed sense of student agency. An exciting CS curriculum will fall flat without accompanying equity-based pedagogy designed to engage all students, and for this, teachers must be supported with appropriate professional development (Margolis et al., 2017). Additionally, there are many excited and motivated teachers who are isolated, lack administrators who understand the importance of CS, and need to fight simply to teach CS in their schools (Margolis et al., 2008/2017; Ryoo et al., 2016).

Integrating computer science is particularly challenging because students must overcome the numerous barriers meted out by inequitable and dehumanizing schooling systems. We will not see increased interest or engagement among women, Students of Color, low-income students, and others who have been historically underrepresented in the field of CS just by overlaying CS education on top of inequitable and dehumanizing public education practices that include (but are not limited to): 1) tracking students in and out of higher-level classes based on gender, race/ethnicity, home language, etc. (Oakes, 1985). 2) unfairly disciplining certain students (such as African Americans) more than others according to race/ethnicity and gender (e.g., Hines-Datiri & Andrews, 2017; Skiba et al., 2011). 3) feeding young men of color into a school-to-prison pipeline (e.g., Christle et al., 2005; Kim et al., 2010; Wald & Losen, 2003). 4) denying Students of Color and low-income students access to rigorous and high-quality math education (such as Algebra I) that serves as a gatekeeper to various STEM-related fields and careers (e.g., Martin, 2009, 2013; Moses & Cobb, 2002). 5) refusing certain students access to quality technology or technology-based instruction, even when the school has access to it (e.g., Warschauer et al., 2004). 6) denying students voice in the classroom about the sociopolitical issues that are impacting them every day (Ladson-Billings in Fay, 2019), and more. Belief systems of adults and students alike based on stereotypes of who can or should do computer science must also be challenged. In other words, students and teachers alike must refuse to believe that only those who have the right to enjoy and excel with computing are males, geniuses, and White.

Public schools have been documented as spaces that, more often than not, dehumanize our students, especially low-income Students of Color. We have seen physical manifestations of such dehumanization with many public high schools locking restrooms throughout the school, denying children the right to relieve themselves as necessary. We have also seen this in the ways that students in these schools are denied opportunities to speak: having a voice is treated as a privilege, not a right. Particularly in low-income community schools, teacher lectures usually dominate class time (Lingard et al., 2003), and this is especially true in classrooms populated by English Language Learners where students should be given more time to speak than teachers (Ho, 2005). The norm

continues to be that students who do not have the money to attend private schools should listen and passively absorb everything that teachers say in a "banking method" that prepares students for predetermined places in the world; those in power gain from "changing the consciousness of the oppressed, not the situation which oppresses them" by teaching them, at a young age, to believe that their culture, belief systems, practices deviate from what is "good, organized, and just" in society (Freire, 1970, p. 55). And thus low-income children of color must be molded and shaped to better "integrate" them into society.

As such, inequitable schooling systems work to dehumanize youth in an effort to keep specific students, teachers, and administrators in their "place" while allowing those of already higher social/economic status to be lifted above and maintain control. In these ways, traditional schooling systems reinforce the inequitable status quo, and rarely ensure that youth's voices and critical perspectives are valued, centered, and amplified in the learning process.

Student agency and acts of resistance: theories informing this paper

In this paper, we focus on the ways that minoritized youth who have been historically underrepresented in computer science – young women, Students of Color, low-income students, English Learners and new immigrants – counter such inequitable schooling systems. We describe student agency as youth choosing to take up space with their voices or ideas and, in turn, having "rightful presence" (Calabrese Barton & Tan, 2019b) in a field that does not necessarily reflect their identities or communities, challenging expectations about who can or should excel with CS in schools and society at large.

Sociocultural theories of learning are central to our examination of student agency. We build on the notion that learning does not take place in a vacuum, but occurs as we engage in the social world of human interactions and relationships that are influenced by unique cultural and historical contexts (Vygotsky, 1978). Furthermore, the way we "do" science or computer science cannot be divorced from culture; while science is often touted as purely objective, both academic and informal engagements with science are made up of discourses and practices that are influenced by culturally-determined power hierarchies impacting whose expertise and knowledge are positioned as meaningful or unwelcome in school (Bang & Medin, 2010; Medin & Bang, 2014). This issue of whose ideas and practices are deemed as "science" or "not science" has shut out millions of minoritized youth from engaging with school science, math, and computer science, as they are commonly denied "rightful presence" in their learning communities (Calabrese Barton & Tan, 2019b). Calabrese Barton and Tan (2019b) define "rightful presence" as:

> legitimate and legitimized membership in a classroom community because of who one is (not who one should be), where practices of that community support re-structuring power dynamics towards more just ends through making both injustice and social change visible . . ..[where teaching] shifts from having the power to extend rights/dictate norms for others, to having responsibility to become learners of the cultural knowledge and experiences and political struggles of newcomers as powerful contributions to society. (pp. 5-8)

We understand the ways that youth take up rightful presence as a form of student agency where learners can experience new forms of participation and "new formations of place" that

challenge traditional power and knowledge (Calabrese Barton & Tan, 2019b, p. 123). This allows for learners to "deterritorialize [school] routines and practices" by reclaiming spaces in science, technology, engineering, and math that were previously deemed "forbidden" for minoritized youth (Perumal, 2015 as cited in Calabrese Barton & Tan, 2019b, p. 124).

Our research is also influenced by the concept of "consequential learning" – learning that builds upon youth's perspectives and what matters most to them (Calabrese Barton & Tan, 2019a; Gutiérrez, 2012). By providing consequential learning opportunities for minoritized youth in computer science classrooms, inclusive forms of knowledge are validated and, in this way, consequential learning is very much part of rightful presence. Further, rightful presence and consequential learning relate to theories of student resistance in schooling, and extend the resistance strategies students engage to counter oppressive schooling structures, in which youth refuse to simply be acted upon, and instead choose to "negotiate and struggle with structures and create meanings of their own from these interactions … [with] *human agency* – the confidence and skills to act on one's behalf" (Solorzano & Delgado Bernal, 2001, p. 315). Building on Giroux's (1983a, 1983b) work describing how resistance involves students both critiquing social oppression and being motivated by a desire for social justice, Solorzano and Delgado Bernal (2001) outline four categories of oppositional behaviors among youth:

(1) Reactionary behavior: oppositional behavior lacking both a critique of oppressive conditions and motivation by social justice;
(2) Self-defeating resistance: students critique oppressive schooling conditions but engage in behaviors that recreate those same conditions;
(3) Conformist resistance: students motivated by a desire to struggle for social justice, yet within the existing social systems and conventions of oppressive schooling conditions;
(4) Transformational resistance: behaviors motivated by both a critique of oppressive schooling conditions as well as a desire for social justice as youth choose to challenge traditional schooling (Solorzano & Delgado Bernal, 2001, pp. 317–19)

At the intersection of conformist and transformational resistance is also what Yosso (2000) describes as "resilient resistance" in which students are motivated by both a critique of schooling and a desire for social justice, but choose to survive and/or succeed in traditional academic contexts in response to racism, sexism, and other microaggressions (p. 180). As Solorzano and Delgado Bernal (2001) explain, however, transformational resistance can take many forms and appear quite subtle with examples of both internal and external resistance. Internal resistance involves students who may appear on the surface to conform to school norms despite experiencing racial microaggressions and oppression (e.g., by performing well in school or seeking a college degree), but are driven to pursue pathways that "give back" to their communities and challenge oppressive norms (e.g., by becoming a social justice educator) (p. 324–5). Such efforts may not be as visible as external resistance in the transformational category where people make visible their efforts while attending demonstrations, through social media, etc.

In this paper, we are interested in exploring how youth enact agency in computer science classrooms as forms of resistance to their broader traditional schooling experiences. We will present several examples of student projects and experiences that

exemplify what we found from observing youth carving space for their voices to be heard – times when student agency became efforts to have rightful presence and experience consequential learning in the world of CS.

Methods

Research question in research-practice partnership

The purpose of our larger project was to elevate the voices and perspectives of students, so that the larger CS for All movement could learn directly from youth about what works and does not work for students' engagement, identity, and sense of agency with CS learning. This paper focuses specifically on student agency in the following research question:

- From the perspective of minoritized students historically underrepresented in computing, what makes a critical difference for their sense of agency in introductory CS high school classes?

To answer this question, we formed a research-practice partnership (RPP) – a sustained, mutualistic collaboration across researchers and educators producing original analyses toward the improved use of research in decision making and educational outcomes (Coburn et al., 2013; Tseng, 2012). This RPP brought educators/students from a large school district on the west coast into collaboration with university researchers at a local university.

Driven by the belief that learning occurs through social activity within larger historical/cultural contexts that impact how students make sense of their learning in the world (Vygotsky, 1978; Wertsch et al., 1995), our methods focused on not only what students articulated as mattering the most for their CS education through interviews, but also close observations of their social interactions with educators and peers while creating projects in their CS classes. Recognizing that learning comes to life in those moments of joint activity (Vygotsky, 1978), our research approach sought to comprehend the larger sociohistorical context of students' CS learning experiences in conjunction with student testimonies to gain a more well-rounded understanding of students' perspectives.

Data sources

Building on these sociocultural perspectives of learning, data sources included weekly ethnographic observations of student-to-student and student-to-teacher interactions in high school CS classrooms, in-depth interviews with focal students at the start of the school year to understand what they really loved and cared about in their personal and academic lives, in-depth interviews with focal students about major projects they created in their CS classes, audio recordings, videos, photos, and anonymous surveys completed by over 3,000 CS students in the school district. Transcriptions of interviews were regularly shared with students for additions or corrections. This was also true of fieldnotes which were either shared in entirety or in sections, depending on partner-teachers' unique

questions or interests. In this way data sources were checked for accuracy by both teacher and student partners in the RPP, while also providing opportunities to engage in conversations across research and practice that improved the quality of the data while informing data analysis.

Study context and participants

The specific context of this study included four CS classrooms: three Exploring Computer Science (ECS) and one Advanced Placement Computer Science Principles (APCSP) classroom, within three different high schools. To respect the privacy of schools and students, we will call the schools AHS, BHS, and CHS. AHS and CHS were typical traditional schools that mirrored the demographics and average test scores of the larger district. BHS was newer in the district as a female-only school, but still reflected the district's racial/ethnic and socioeconomic diversity. All three schools (and the entire school district) served majority Students of Color from low-income communities, with the larger district enrolling 73.5% Latinx, 10.5% White, 8.2% Black, 4.2% Asian, and almost 80% students qualifying for free/reduced price meals. At AHS and BHS, ECS was a 9th grade requirement. All of the teachers had more than seven years of experience teaching ECS, and one of the teachers had been teaching APCSP for three years at the time of the study.

The first author partnered with the teacher at AHS who taught both ECS and APCSP, and the second and third authors partnered with the other two teachers in their ECS classrooms at BHS and CHS respectively. Together, we identified five focal students in each of the four classrooms to follow more closely than others during the school year. Focal students were chosen based on demographics and prior CS experience. More specifically, we wanted focal students to all be Students of Color (therefore coming from communities historically underrepresented in computing) with little to no prior CS experience, as well as reflect male, female, and non-binary perspectives (see Table 1 of focal students below).

As researchers got to know focal students and their teachers, they often were invited to attend various events and activities outside of CS class time that were organized by, or involved student and teacher partners. Such experiences supported deeper relationships and knowledge-building about what mattered most for students' sense of agency with computing within the larger context of their lives.

Table 1. Description of focal students.

School	AHS (ECS Classroom)	AHS (APCSP Classroom)	BHS (ECS Classroom)	CHS (ECS Classroom)
Gender Identity	• 3 females • 2 males	• 2 females • 1 male • 1 non-binary	• 5 females	• 2 males • 3 females
Race/ Ethnicity	• 5 Latinx	• 5 Latinx	• 3 African American • 2 Latina	• 4 Latinx • 1 Latinx/African American
Prior CS Experience	• No prior experience	• No prior experience	• 1 student learned some programming in middle school; • No prior experience for all others	• 1 student learned some programming in Honduras; • No prior experience for all others

Data analysis & coding

Fieldnote and interview data were coded using the Dedoose online qualitative analysis software program. A grounded theory (Glaser & Strauss, 1967) approach informed our coding process as we sought to search for codes and themes emerging from continuous and systematic review of the data corpus that illuminated our understandings of what student agency looked like in CS learning contexts for minoritized youth. Building on our sociocultural approach to understanding learning, our unit of analysis focused on agency in relation to interactions between teachers and students, as well as students with their peers. We employed both "top-down" and "bottom-up" approaches to making sense of the data so that larger sweeping patterns across the data corpus could inform our coding scheme in conjunction with educational theories influencing our sense-making in classroom spaces.

For example, our research team began by creating a coding tree based on ideas that emerged from analyses of over 3,000 student pre-surveys focused on student engagement and agency with CS (Ryoo et al., 2019); these surveys were administered across the district in fall 2018. At the same time, we drew upon theories regarding students' community cultural wealth (Yosso, 2005) that students may have drawn upon in CS classrooms, the social interactions informing their learning experiences (Vygotsky, 1978), as well as ideas related to practice-linked identity (Nasir & Hand, 2008) and critical science agency (Basu, 2008; Basu et al., 2008) that informed our initial thinking about issues of engagement, identity, and agency. Based on this top-down approach to coding, we came up with initial codes related to students' interests, such as "address real-world social/political issues," "personalize projects," and "community cultural wealth" that emerged as important to students in the pre-surveys, while also reflecting broader patterns across the different classrooms spaces. Pooled Kappa scores on the team's inter-rater reliability test for our initial rounds of coding the surveys were between 0.93–0.95, falling in the "excellent" range recommended by Miles and Huberman (1994) for qualitative data analysis.

Individual researchers began by coding their own fieldnotes, with the fourth author using the coding scheme to code fieldnotes from each of the other three researchers in order to ensure that the codes made sense and were used in the same ways across classrooms. As we coded, we jotted down questions and/or clarifications that arose when using the existing codes, as well as potential additions or deletions from the coding scheme. Following the coding of every 5 fieldnotes, the team would meet and discuss edits to the coding scheme while sharing various coded excerpts. This process illuminated which codes seemed to be emerging more or less across specific classrooms, and what began developing as common threads and interesting contrasts in different learning spaces. This process resulted in important shifts in our coding tree that helped us clarify what we meant by codes such as "engagement" or "student agency." For example, the separate code for "personalization of projects" became embedded into the "student agency" code as we began to see this as an agentive act in the classroom, but we also began to discuss the nuances of personalization which sometimes took on political or apolitical meaning depending on the project and classroom context. With every change, we would return to previously coded fieldnotes and re-code based on team discussions.

After the first round of coding all fieldnotes, we took the coding scheme and used it to code all student interviews with researchers, again, coding their own focal students' interviews and the fourth author coding across classrooms. As we coded the first five interviews, we decided to add additional codes that were specific to the types of conversations the interview questions surfaced that were not necessarily explicit points of discussion in classroom spaces. More specifically, we built in codes for students' passions/interests, perceptions of CS, future life goals (career and otherwise), home/personal life details, and input on what students articulated as "working" for their engagement in CS classrooms.

Following this round of interview coding, we returned to the fieldnotes and did another round of coding with the revised coding tree. We limited our coding to the excerpts that had previously been coded with any of the following: Engagement, Agency, Identity, Addressing Real-world/Political Issues, Student-Driven Learning, Cultural Relevance. This way we could dig more deeply into both similarities in students' perspectives/experiences as well as lines of contrast across the classrooms to better inform our understanding of student agency.

Findings

Finding 1: The positive relationships between student engagement, agency, and enacting positive social change

As noted above, our coding scheme was informed by findings from an analysis of student surveys distributed throughout the school district in Fall 2018 (Ryoo et al., 2019). In response to a question asking students to 1) describe a personal interest/passion, as well as 2) how they might use CS in that area of interest/passion, the largest group of students (41% of 1,968 students) described wanting to use CS toward inventive purposes. Whether that was algorithms for accurately predicting average scores for baseball players, or creating free programs that connect patients to health care professionals, students were engaged with visions of themselves as active creators with computing, not merely users (Ryoo et al., 2019). Furthermore, nearly a third of survey-takers specifically articulated ways that they wanted to use CS toward impacting positive social or political change. They wrote things such as:

- "Something I would like to improve using computer science would probably be **school systems** and the way students are analyzed, evaluated and helped out."
- "I will design a computer algorithm that would **evenly distribute any and all resources** to everyone based on their needs in order to better operate society."
- "Something that I'm really passionate about is **helping others especially the disabled**. I would like to change the world by designing better prosthetics."
- "I would program 3 different robots that would go around the city to pick up recycle bottles, Garbage and green waste." (Ryoo et al., 2019, p. 14)

Triangulating these findings with data from classroom observations, examinations of student work, and interviews, we found students both demonstrating and verbally

articulating the same desire to use CS toward actively making an impact on the world around them.

More specifically, one of the most common code co-occurrences in our analysis of observation field notes was between "Agency" and "Engagement" (co-occurring 84 times among 306 uses of the "Agency" code). In our coding of interviews, these two codes co-occurred the most out of all other code pairings. Based on our code definitions and understanding of agency as a form of taking up rightful presence in learning contexts, this suggests a positive trend between student engagement with computing, and opportunities to personalize projects, take ownership of one's learning, and actively create with CS in ways that directly impact one's community. Looking more specifically at our code for "Addressing Real-World/Political Issues," this co-occurred most with the "Engagement" code among field note analyses, and most with "Identity" and "Engagement" codes in interview analyses. These themes in our analyses highlight a positive relationship between engagement and agency, with an emphasis on students wanting opportunities to use computing toward directly impacting their communities.

Finding 2: Students carving out space for their voices to be heard

Yet what did "agency" and "engagement" look like for minoritized youth across the classrooms? And how did the students articulate these concepts within the context of their own learning?

In the process of analyzing students' interviews and projects over the school year, a common theme emerged across the classrooms regarding student agency, specifically as a form of resistance and a means to make space for oneself. As articulated by Solorzano and Delgado Bernal (2001), agency as resistance can be complex and layered, taking different forms as youth seek their rightful presence in the classroom. In what follows, we share three examples (one from each school) chosen to illustrate how youth used their unique voices to promote their ideas while using computer science as a tool for resisting educational contexts that have historically denied them the space to do so. While we observed other instances in which students demonstrated agency with computing – from creating websites against gun violence to designing apps for the purpose of educating younger siblings about health issues – the examples that follow are highlighted because of the ways they can deepen our understanding of what it means to make space for one's voice and resist dehumanization in CS and schools.

Example 1: Heaven, Jordyn, Khia, and Tatiana's Agency: repurposing computer technology to centralize racialized grief while commemorating the life of the late Nipsey Hussle

Heaven, Jordyn, Khia, and Tatiana were all high school freshman at BHS. The girls, who were all the best of friends, met in the weeks leading up to their 9th grade year in a summer school program. In describing their schooling experiences, the girls noted the strengths and challenges associated with being Black, female, and low-income in their school context. On the one hand, their shared experience as multiply minoritized Black girls from urban communities allowed them to establish an instant connection

with one another. The girls regularly described themselves in-person and on social media as a "family," playfully assigning familial titles to one another like "daughter" or "sister."

On the other hand, their intersecting identities often placed them on the racialized margins of the school. The girls described being isolated, overlooked, hyper-surveilled, and stereotyped by their teachers and peers on account of their racial identities. Heaven captured the social isolation when she described the stark differences in race and class that she and her friends experienced at school. She said that the rest of the students "are all from different zip codes, but it seems like they're all from little rich neighborhoods around here. So its kinda awkward … Then our group is like the little Africans out of all the ninth grade." Additionally, the girls regularly experienced racial stereotyping. Jordyn noted that they are often received as "ghetto," while Heaven said, "We're loud and stuff like that. And they stereotype us off of that. Like they all think we're the bad group because we're loud." Jordyn, who remembered being "kicked out for going to the vending machine" captured the culture of radicalized surveillance and Black girl push-out when she explained, "Everything we do in dance class, they email [the principal] about. And apparently the middle schoolers in our dance class want [all of us] out of the class."

Although the girls encountered a myriad of racialized policies, practices, and pedagogies that hindered not only their learning, but their sense of belonging in the school, they nevertheless fought against systematic erasure and push-out in creative ways. After describing how Black girls are misperceived and mistreated in the schooling context, Heaven boldly asserted that "The people at this school … If they don't like how the way I talk or something like that I don't care, that's their problem … I don't have to worry about them … There's nothing wrong with my outside appearance." Their determination to be seen and valued as low-income Black girls was palpable in their creation and discussion of a politicized electronic-textile project in their ECS class. Following the gruesome murder of community activist and rapper Nipsey Hussle, Heaven, Jordyn, Khia, and Tatiana described being silenced, policed, and targeted in school for grieving a racialized loss. In a focus group interview, the participants discussed a time in math class when they used their school computers to live stream Nipsey Hussle's funeral. Although other classmates were watching Netflix shows and using social media at the same time, the participants were publicly shamed for using class time to watch "just another idiot thug" by their math teacher. When the participants advocated for themselves, the teacher told them that this was an "inappropriate use of school computers." The following week, when the girls used their cellphones to play Nipsey's music aloud while they worked on their electronic-textiles project, they were told by school security that it was against the rules to use cell phones or listen to music during school. Cumulatively, the use of school policy to silence and penalize expressions of racialized grief sent a message to the young women that their lived realities were not valid in the school context.

It was in response to this hyper-policing that the four students subversively repurposed computer technology to center and make visible their grief in their introductory computer science class. Their ECS teacher, Mr. A, encouraged the students to center topics, issues, and interests of personal importance to them in their electronic-textile projects, and in doing so, provided the students an opportunity to center their racialized grief in a way that was deemed "appropriate" for the school context. Tatiana noted that Nipsey Hussle

"meant a lot to us and he had recently passed away, so we just felt that we should pay tribute to him since he did so many great things in our community." Khia added, "we just felt the need to dedicate it to him because he impacted our community and us and some people personally, but mainly us and for the youth in our community, trying to help people get off the streets and get a job and have a future." Thus, the girls proceeded to design and create an electronic-textile banner out of felt with Nipsey Hussle's name written in the sky. They programmed the banner to flash various LEDs sewn into the felt at different times (see Figure 1 below).

By using the electronic-textile project to spotlight Nipsey's death, the students avoided being punished for talking about him outside of Mr. A's classroom. Likewise, programming the circuit playground to play a Nipsey Hussle song enabled the girls to listen to his music during class without pushback. Ultimately, the decision to tether politicized issues to CS in the school context was a strategic attempt to renegotiate the boundaries of what is "appropriate" for Black girls that experience hyper-policing and racialized violence.

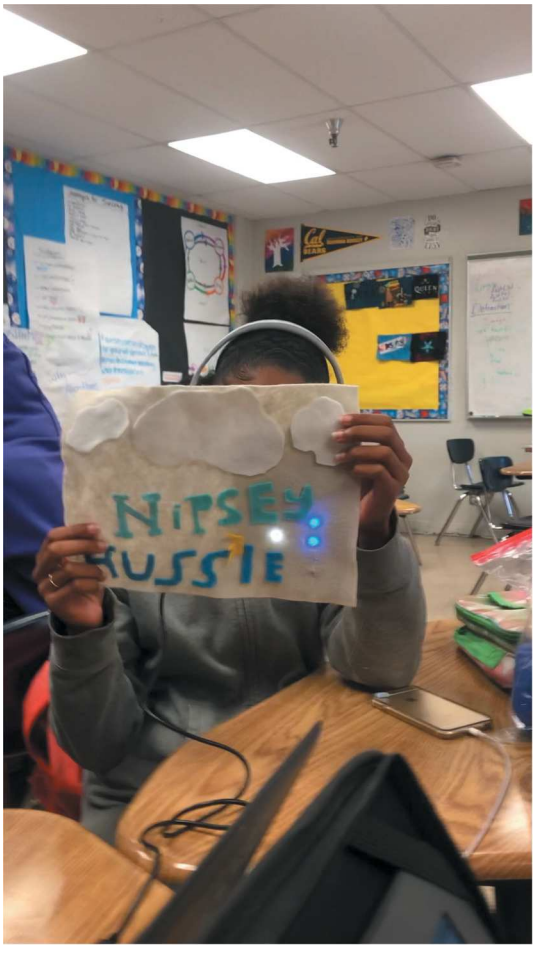

Figure 1. Tatiana holding up her group's Nipsey Hussle electronic-textile project.

As articulated through interviews and this Nipsey Hussle project, the four students were acutely aware of institutional racism in their school and used CS tools to celebrate not only this artist, but also their own culture and existence in ways that represented rightful presence and transformational resistance. Rather than demonstrate reactionary behavior, self-defeating resistance, or conformist resistance, the young women created a tribute to Nipsey Hussle in direct opposition to certain teachers' policing of Black culture and grief. While their CS teacher welcomed their plans to create a Nipsey Hussle project, others were telling the students to leave their race, culture, and community at the door. Yet, refusing to be silenced, the girls programmed a project that represented Nipsey Hussle's positive impacts on their community, physically taking up space and declaring their right to be Black and proud while also requiring that people see, rather than ignore, their grief.

Example 2: Alvaro's Agency: Computer Science for Community Activism

Alvaro was a senior at AHS, and had never taken a computer science course before enrolling in APCSP. He identified as a "Queer POC (Person of Color)" or "Queer Latino," using gender pronouns he/they, and one of his greatest passions was community activism. Alvaro had been bullied in middle school and believed it was important to help people experiencing marginalization as he once had: "I consider myself an activist … I like to be active in certain communities and uplift voices of people who aren't heard. I like being in different organizations or programs that allow me to do that and really be a voice for certain people and help amplify others." Alvaro was central to reforming the Gender Sexuality Alliance (GSA) at his school, and he also spearheaded a campaign to create a gender-neutral restroom on his campus. He named this as one of his proudest accomplishments, noting that this multi-stalled gender-neutral restroom was only the second to be opened in the entire school district. Another accomplishment he was proud of was winning the fashion competition at his school during an event called The Neoclassic, that is organized by the school fashion club leader/computer science teacher (Ms. M). Alvaro had an interest in fashion, but had never designed or sewn clothes before. However, he decided to sign up to compete and spent many hours in Ms. M's classroom where she held all her computer science classes. He noted that he came to see Ms. M as a "mentor," and that when she encouraged him to enroll in APCSP (stressing the fact that fashion design and CS share many similar problem-solving practices), he decided to try it. Before that, he had thought that CS was "unimportant to me. It wasn't part of my path, I guess." Alvaro explained that he saw himself becoming a neuroscientist in the future because he wanted to help people with issues related to brain cancer, which his late grandmother had suffered from. He didn't initially feel that CS would support his career in neuroscience and medicine. However, as the school year progressed, he saw APCSP as one of his most challenging and therefore most interesting classes that he "actually ha[d] to study for," and that he really enjoyed the course.

One of the reasons why this shift for Alvaro came to pass was because he found ways to connect CS to his personal interests in community activism and improving the lives of others. More specifically, for his AP exam "performance task," he decided to create a "mental health app" called "Breathe" that "can help you destress and not really feel like you're suffocating … you really just need to breathe and not have [that] feel[ing] like so much is on your shoulders all the time."

The app included four different features to help one re-center and destress, including: 1) Words of Affirmation, 2) Breathing Exercises, 3) Mini-Game, and 4) Journal (see Figure 2 below).

The Words of Affirmation (Figure 3) offered statements to help users find direction in the face of emotions such as anger, anxiety, etc. For example, if one noted they felt "sad," the app replied: "Every day I have the power to choose, and today I choose happiness." Alvaro explained that his app had words of affirmations "to help reassure you that you're sad, not necessarily because it's your fault, but you could choose to be happy. Or when you're stressed you can repeat the words on the screen and feel less stressed . . . and make you feel better." The Breathing Exercises (Figure 3) included four different exercises for

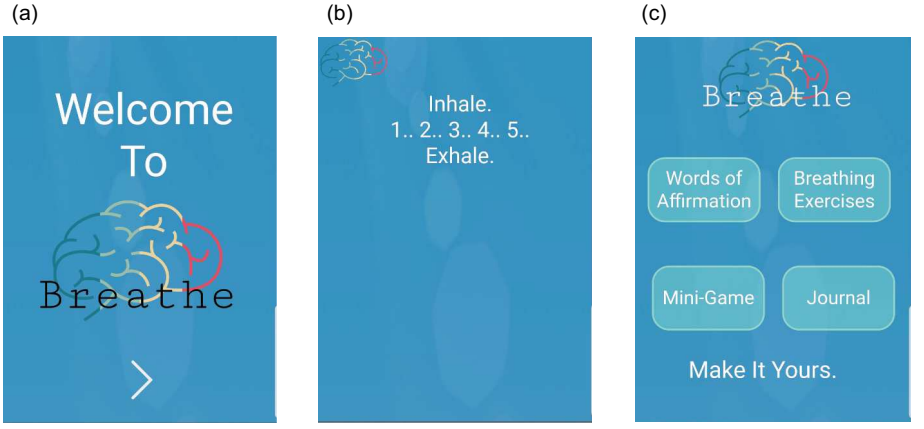

Figure 2. Alvaro's mental health app.

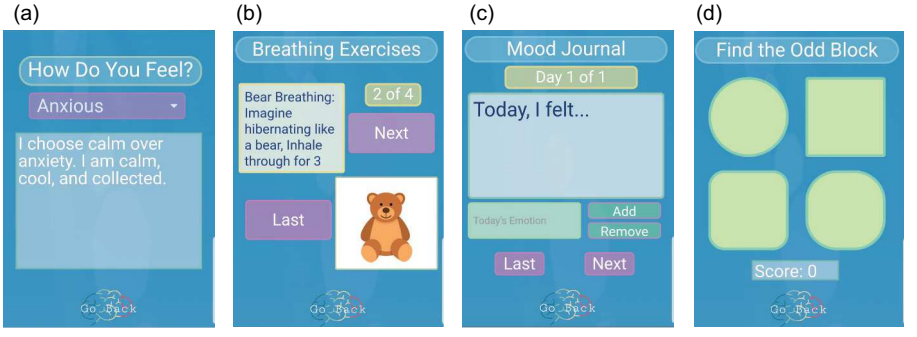

Figure 3. Alvaro's app: words of affirmation, breathing exercises, mood journal, and mini-game.

meditation, while the Mood Journal (Figure 3) allowed users to track daily emotions toward increased consciousness about one's feelings. Finally, the Mini-Game (Figure 3) was a clicker game in which "you could only win so that you could feel like, even within the game or at least for a certain moment, you're on top of the world and you won something in the day."

Unlike others who were working on their apps until the last minute before they were due, Alvaro found himself finished creating his app well before the due date. He noted, "What inspired me to create my app was seeing all my friends really stressed and me being stressed because, you know, being a senior is stressful. And on top of that, having to work, and being in so many different programs or working for different organizations and being in different clubs, and college apps is really stressful. So I wanted to create it for people, not just myself, but for others like my friends and people in general who day-to-day feel like they're stressed." For Alvaro, he took great pride in creating something that was "useable and functional" and that his app "definitely shows about what I care about, like mental health and mental well-being, and I think it's a form of activism since I'm bringing awareness to it … while also being able to relieve some mental health issues or day to day issues."

For Alvaro – who enjoyed the challenge of CS but did not initially see how it could relate to his world beyond the APCSP classroom – computing proved to be an important tool when he realized how to wield it toward community activism. With a desire to build awareness around issues of mental health that are usually ignored during the school day, Alvaro positioned himself as someone who could counter the daily stress experienced in public school by his Peers of Color – including friends who also identified as queer and had survived severe bullying the way he had. Alvaro defined himself as a community activist who could use CS to improve the lives of those around him, embodying behaviors aligned with transformational resistance and external resistance, as he took action to counter the stress that peers experienced in school. In these ways, creating this app was more than just the personalization of a CS assignment; agency meant envisioning a greater purpose for the project toward community impact.

Example 3: Danielle's agency: Engaging with what she loves and challenging deficit notions of her CS abilities

Danielle was one of the many freshmen at CHS taking ECS. With no prior experience with CS, she often described it as being "too hard." Her true passion was reading literature, especially mystery novels and sci-fi thrillers. In fact, she loved reading books so much that she wanted to make it a part of her career by sharing books with others as a high school English teacher. She aspired to be the first person in her family to go to college and actively worked to maintain good grades. Outside of school she loved to dance Bachata with her church community, and shared that she loved "Spanish music." Identifying as half Black and half Latina, Danielle admitted to being "more in touch with [her] Hispanic side" as she had spent most of her time with her Mexican mom and grandma. She recalled her love of music and dancing stemming from years of listening to Spanish music while cleaning with her family. It was evident that family was important to Danielle as she often spoke about her sisters, mother, and grandmother.

In her classroom, Danielle – like many of her peers – appeared to be disengaged from her initial ECS course material. She often stood up from her desk, walked to her peers' desks and sparked up a conversation that could be heard from across the room. As a result, Danielle was frequently publicly scolded in front of the entire class by her teacher, Mr. R. Although there were playful instances between Danielle and Mr. R, private conversations revealed that Mr. R felt that Danielle simply was not doing her work. Earlier in the school year, she was often described as "not the best student" which were feelings that clearly manifested within the classroom. Danielle was often publicly called upon to provide answers to questions posed by Mr. R, yet ignored when she had a clarifying question or needed her work checked for her grade. It did not help that the classroom was overcrowded with forty students, making it difficult for Mr. R to be able to get to all of his students for one-on-one check-ins every day.

However, the teacher-to-student ratio (40:1) was not the only contributing factor. During a researcher and teacher meeting after class, Mr. R expressed his frustration with the class. He described the students as his "worst class" and disclosed that he felt that his students were very immature. He added that Danielle continued to "do nothing," a sentiment that was challenged by the researcher. The researcher then shared classroom observations with the teacher that illustrated how Danielle may have appeared disengaged, but was often talking with peers because she was ahead in the material and had taken it upon herself to teach her friends. Throughout the course of one academic year, Danielle demonstrated her resiliency as she refused to be forgotten in the sea of students. Every week she would yell, "Mr. R!" from her desk with the hope of getting her classwork checked off. After looking at this evidence, Mr. R readjusted his low expectations of Danielle and began to develop a more respectful and playful teacher/student relationship with her.

In Mr. R's classroom, Danielle began to connect her CS projects to areas of interest that were important to her, making CS work for her. While this meant positively impacting the world for Alvaro through an app and utilizing CS to heal and process black death and dying for Heaven, Jordyn, Khia, and Tatiana, for Danielle it meant proving to Mr. R and, most importantly, to herself that she was capable of doing CS. Danielle had no intention or desire to pursue CS, and in many ways reflected the reality of many of her classmates. In other words, Danielle was not an exception. Danielle's story is of particular importance in that she very frequently expressed that CS was much too difficult. Still, Danielle persisted and, by doing so, she resisted. She completed every assignment including the creation of a website which she was very proud of. Danielle had created a website about her favorite things: jeans, sneakers, and novels (see Figure 4). When prompted to speak to her subject matter choice she initially stated, "I don't know, Mr. [R] said to pick things we like so I chose jeans, Adidas and mystery books." However, upon digging deeper Danielle expressed true pride in her learning when she stated:

> I felt excited at the end of it when I saw everything. Because at the beginning I was like "Oh, how am I going to do this? It looks so hard." When I saw everything come together at the end, I was really happy. I was like "Oh my God, I actually did it and it looks nice."

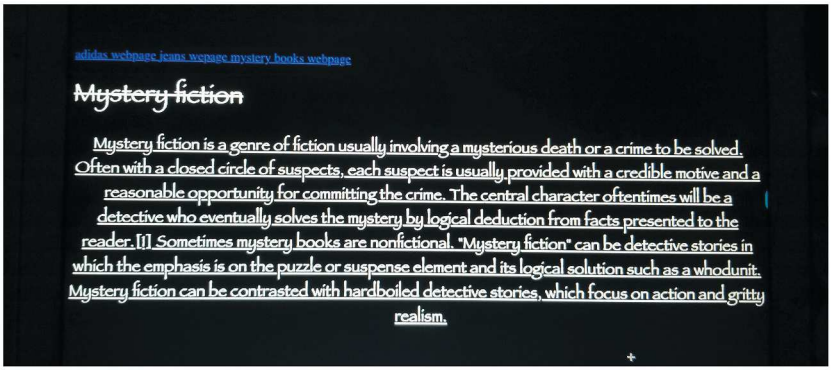

Figure 4. A section of Danielle's website describing her favorite genre of literature.

This theme was extremely common for Danielle and other students within her class. Although Danielle did not wish to pursue CS as a career, she chose to not only take space, but make space for herself. She not only disrupted her teacher's initial deficit views of her capabilities with CS but challenged her own views of herself.

If one did not get to know Danielle and her perspective of the CS classroom, one would think that she was slightly disengaged and only completing assignments when she was told to do so (e.g., completing the website project). Yet Danielle shared a different perspective with us. Classroom observations and interviews revealed how, internally, she battled a lack of confidence with CS that she worked to overcome. At the same time, she sought to resist Mr. R's low expectations of her engagement and ability, seeking to prove to both herself and the teacher that she could create her own website. While her project was neither political nor explicitly addressed issues of social justice, her tenacity to be seen/heard by Mr. R, and her persistence in completing CS served as a form of resistance to anyone (including herself and her teacher) who believed she was not capable of succeeding in CS. This was especially important for Danielle as someone who would be the first in her family to go to college. As such, her engagement with CS represented resilient resistance (Yosso, 2005), which was a common form of student agency visible in the focal classrooms where youth sought to make their presence known.

Finding 3: Instructional strategies for supporting student agency

Of course, the students described in this paper did not exist in worlds separate from their peers or teachers. As we know, pedagogy in the CS classroom matters (e.g., Ryoo, 2019), and there was a range of ways in which teachers engaged with youth across the classrooms that both encouraged and discouraged youth in recognizing how CS learning could be consequential to their personal and sociopolitical interests. In what follows, we consider what those instructional strategies were that influenced how students demonstrated agency in the three CS classrooms.

At AHS, Ms. M believed that teaching computer science was related to preparing students to engage with "democracy and freedom." She believed it was important to consider how our engagements with computing, as well as computer scientists' decisions

affect not only ourselves individually, but also the larger world. She noted, "it's always that core: what are the implications for us as individuals, for us as citizens of not only this country, but also the world? And so knowing that something like your convenience is somebody else's work?" Thus, she felt it was her responsibility to support youth in developing their unique voices that involved taking a stance on different issues in computing while critically examining the role of CS in our larger society.

As Ms. M explained her instructional practices she said, "I feel that students learn best when there's inquiry, when they're making, when there's authenticity, when they're involved and they have choice." Relatedly, Ms. M employed instructional strategies that supported room for experimentation, "diversity of ideas," and safety to "take risks" and "ask questions." She noted that creating an equity-oriented classroom means that "students [should] have multiple entry points and for the lessons to resonate with as many people as possible." Such pedagogical approaches, in turn, were supported by the ECS and AP CSP curricula that were replete with activities giving students opportunities to create projects reflecting their own passions or interests.

Thus, to create a space where students like Alvaro could take on computing as a tool for mental health and resistance against stressful schooling practices, Ms. M would not only allow students' interests to drive the direction of their learning, but also would regularly make connections between CS content learning and computing's impact on the socio-political world. For example, students debated about the pros and cons of living in a cashless society, thinking deeply about how computing tools could "widen the poverty gap," negatively impacting those without technological tools in poorer communities around the world. Students described how food vendors in Mexico could lose business or how the monetary activities of vulnerable populations (e.g., undocumented immigrants) might get tracked. Furthermore, Ms. M regularly discussed the privacy issues associated with using computing tools as students created websites, apps, and video games. Everything was understood through a critical lens recognizing that the programming decisions students made in their projects had both direct impact on the social world as well as unintended consequences that they must consider in their creation processes. In these ways, Ms. M was teaching her students to be thoughtful but agentive in their computing work.

At the same time, Ms. M maintained high expectations for all her students and regularly checked-in with those who seemed disengaged or distracted. This, also, was a key instructional strategy. Rather than assume disengaged students were slacking off and could not be helped, she took on the responsibility of assuring that *all* students to be engaged in the learning and measured her successes not on the achievements of her best students, but on the achievements of the students who struggled the most. As such, she would get to know her students, find out what motivated their interests, understand what was happening in their personal lives that might be impacting their experiences in the classroom, and explicitly call out the need for mutual respect and trust within their shared space. These pedagogical efforts created the context in which students could feel empowered to use computing to address issues in their school and communities.

Within the context of BHS, Mr. A's support of student agency also was rooted in an inquiry-based approach to teaching. He explained, "I want students to ask questions, figure things out on their own, own their learning." He believed in the importance of

students' own questions motivating their learning in an environment supported by collaboration with others. Relatedly, Mr. A knew when to stay out of the students' way so that they could share their voices in the classroom. Unlike Heaven, Jordyn, Khia, and Tatiana's math teacher, Mr. A welcomed the students' connections to identity, community, and issues related to Black death in the learning context. He did not challenge their voices, but made room for them to be heard.

Part of this extends to another instructional practice regarding a focus on creativity. Programming in Mr. A's classroom was rooted in the process of making and creating objects of students' interest and design, not programming for programming's sake. This, hand-in-hand with an inquiry-based approach provided the context necessary for students to be able to use computing to express their unique selves.

Of course, inquiry-based curricula like those for ECS and AP CSP are designed to encourage students in building their personal interests into their work. But our data revealed that, across the classrooms, simply following a curriculum is not enough. Returning to Danielle's experience above, her teacher believed in an inquiry-based approach and encouraged students to build on their personal interests while following ECS lessons. But students wanted more than just to personalize their websites: they also needed Mr. R's attention and high expectations for their abilities and work. And while Mr. R initially did not recognize Danielle's effort to engage with computing, his openness to changing his perspective about her and willingness to look at the data with his partner researcher made a significant difference in the way he approached Danielle in the classroom. It showed him Danielle's true intentions to learn and reflected the ways that shifting pedagogies matter for students to be able to take on agentive and transformational approaches to their learning.

Thus, teachers' instructional practices – such as specifically focusing on critically examining CS creations, allowing students to contextualize their CS projects in issues that they care about, supporting inquiry-based learning and creativity, celebrating students' voices, allowing room for experimentation and risk-taking, etc. – play an important role in whether or not students feel a rightful presence in their classrooms toward resisting oppressive forces in their educational system and communities. Danielle offers an example of a student who fought to learn and create, but there are many who turn to reactionary or self-defeating resistance instead when in similar situations as Danielle. Teachers must be actively attuned to the lives and experiences of their students so that they are able to thrive and critically understand their own potential to use computing for positive social change as agentive members of our communities. The ultimate goal is for students to be able to be agentive and engage with transformational resistance that positively impacts the world beyond the CS classroom, not for students to need to take on a resisting stance within the CS classroom itself. For this to happen, teachers need to create contexts in which students feel a rightful presence and can own their identities and experiences in computing.

Discussion & conclusion

Student agency in computer science: resisting deficit stereotypes and oppressive schooling structures through computing

The student experiences drawn from classroom observations, student work, and interviews illustrate varying forms of student agency and transformational resistance that we saw across the focal schools. While all the students described in this paper were exceptional in their own ways, their approaches to, and uses of CS were not out of the ordinary across the different classrooms. It was not uncommon for students to engage with their CS projects as a way to take up rightful presence in their classrooms, finding forms of consequential learning in CS that reflected who they were and what they cared about. Rather than sitting back and learning passively, students were eager to create projects that shared their unique voices in ways that resisted deficit stereotypes about their abilities, toward countering oppressive schooling structures. From the ways that the young women at BHS used CS tools to commemorate Nipsey Hussle and reflect their own culture and existence toward demanding rightful presence and transformational resistance in the face of institutional racism, to the ways that Alvaro at AHS used CS to increase awareness and healing in the face of stressful schooling contexts, to the way that Danielle resisted low expectations of her CS abilities, students made meaning of their computing learning experiences in ways that moved beyond the classroom.

Centering students' lives, race, power, and privilege in classroom learning

However, as stated earlier, teacher practice plays a critical role in whether or not youth have opportunities to use their voices and challenge oppressive schooling contexts and larger community issues. The fact that all of the teachers actively encouraged the youth to create unique and personalized projects was, in itself, an important first step for youth's voices to be heard. That being said, simply allowing students to choose the direction or focus of their projects is not enough. The three examples shared in this paper reflect the ways that CS classrooms can go a step beyond to provide productive contexts for youth agency: where students can feel that their effort results in consequential learning, and where they can have a rightful presence in CS spaces. This means that curricula and pedagogy need to acknowledge how the CS classroom is not divorced from the larger sociocultural and political contexts within which they sit, and that students should not have to fight to have their voices and perspectives heard within the CS classroom itself.

Many students actively want to make their communities and the world both safer and healthier places where all people can thrive (see, for example, Cammarota & Fine, 2008; Morrell, 2008; Ryoo et al., 2019, etc.), but many schools put limits on students' political resistance within school learning. This is why increasing students' critical socio-political consciousness is one of the central tenets of Culturally Relevant Pedagogy, and yet this tenet is often neglected, even as teachers believe that they are following culturally relevant instructional practices (Ladson-Billings, 2014). In the Culturally Responsive Computing classroom, learning with technology should go hand-in-hand with youth learning about their own intersectional identities. As such, "technological success should consider who creates, for whom, and to what ends rather than who endures socially and

culturally irrelevant curriculum" (Scott et al., 2014, p. 10). CS teachers and curricula need to understand why students' understandings of systemic inequality in both schools and the CS world at large should be part of CS education.

Indeed, the history of institutionalized racism, sexism, and heterosexism in tech must be taught in CS education, thereby challenging the inequities built into computer programming that replicate social divisions in the "New Jim Code." Students should be explicitly encouraged to use computing for social good while critiquing and disrupting the power, money, and politics driving computing creations (Benjamin, 2019a; Vakil, 2018). In order to get there, teachers must acknowledge and value the unique perspectives and wealth of knowledge that youth are bringing into the classroom, encouraging those connections between CS, self, and transformative social change.

However, this is no easy task. As Calabrese Barton and Tan (2019b) explain, such pedagogies are not always long-term nor as straightforward as one might hope. They cite Gruenewald (2003) while explaining how even when educators seek to be supportive of youth voice and consequential learning, students "do not necessarily have unfettered leeway to freely place-make toward rightful presence" (p. 165) because both youth and educators must constantly butt their heads up against the market models of competition and achievement in STEM that values certain knowledge and cultural practices over others. This tension is particularly visible in CS education and career fields where minoritized youth will not find many role models who look like them or come from their communities. There is great responsibility on the shoulders of teachers and curricula to create contexts where youth feel free to envision what they want CS to be that allows expansive thinking beyond those "market models" that limit students to the visions of middle-class capitalist values.

Furthermore, as visible in mathematics education research, there are complexities to humanizing pedagogies that make space for youth voice. Gutiérrez (2013) describes how the mathematics education research community has been examining the value of the "sociopolitical turn" that moves beyond simply engaging analyses around social interactions, but actually "privilege[ing] the voices of subordinated groups and forefront[ing] the politics and power dynamics that arise from sites of interaction" (p. 39). Yet applying these ideas to pedagogy is complex because it requires, 1) offering professional development that helps educators understand and integrate political knowledge with subject material while recognizing that teachers do much more than just teach subject matter content/practices, 2) considering what success in math (or computing in the case of our project) looks like beyond a test score or career pathway, and 3) analyzing issues of power and identity without treating it simply as an "intellectual exercise" (Gutiérrez, 2013). Pedagogical efforts that support learning contextualized in the real issues of community, power, and resistance that students care about can be problematic when teachers are expected to simply enact instructional practices for student agency without a deeper reflection on their own perceptions of culture, social justice, student voice, and location in the larger socio-political context (Leonard et al., 2010). Furthermore, this work does not happen through one activity or project but takes time. As Gutstein (2003) shared in his own social justice mathematics efforts, "[student] growth was often accompanied by contradiction, ambivalence, and equivocation" as students were in the early phases of making sense of ideas, analyzing power dynamics, and constructing their voices in the world (p. 53).

Recognizing this, we highlight the importance for the larger CS for All movement to encourage teacher professional development and curricula that actively create space for students to both work through their critical/political ideas as well as be heard. There needs to be increased effort to support youth voice, but also to ensure that CS learning is consequential to the varying ways that youth see meaning in their lives. Additionally, teachers need to be properly supported in their profession. This means offering teachers high-quality PD and materials, coaching, and peer-support.

CS is touted as a field that supports creativity and where anything is possible. If this is true, then the CS classroom should also embrace this ethos of innovation and change. CS curricula and classrooms should be at the forefront of making schools more humanizing and positive spaces of learning for all. And, as we have learned from the students themselves, student resistance and a commitment to social justice are critical to making that happen.

Note

1. Not all Asian groups are represented in CS. Furthermore, we recognize that Asians are a very diverse population that encompass over half of the population of the entire world and that Asians experience race-based discrimination in the field of CS and the sciences at large as well (see, for example, Berdahl & Min, 2012; Gee & Peck, 2018).

Acknowledgments

We would also like to thank our partner teachers and students (anonymized here to protect their identities) for their amazing insights and our collaborative work together.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This research was funded by the National Science Foundation (CNS-1743336), as well as the Bill & Melinda Gates Foundation (OPP1183584). Any opinions, findings, conclusions and/or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of our funders.

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