



Centering Minoritized Students' Perspectives: What Makes CS Learning Consequential

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ABSTRACT

Taking a justice-oriented approach to equity in Computer Science (CS) education, this paper questions the dominant discourse in CS education and asks what truly makes CS learning consequential from the perspective of youth. We define CS learning as consequential by focusing on its transformative impact on youth identity, agency, and perceptions of the world within and beyond CS classrooms, regardless of whether or not they pursue CS in the future. Our research-practice partnership used qualitative data, specifically longitudinal interview data with 30 students up to three years after they first experienced a high school CS class in a large public school district on the west coast serving majority Latinx, urban, low-income students. Our findings suggest that in order for CS learning to be meaningful and consequential for youth, learning must involve: 1) freedom for youth to express their interests, passions, and concerns; 2) opportunities for youth to expand their views of CS and self; and 3) teacher care for students, learning community, and subject matter. The findings have significant implications for the broader "CS for All" movement and future efforts to reform policy agendas aiming for a more justice-centered CS education.

CCS CONCEPTS

Social and Professional Topics • Professional Topics • Computing Education • K-12 Education

KEYWORDS

Justice-centered CS, K-12 Education, Equity, Consequential Learning, Student Voices

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1 INTRODUCTION

From President Obama's 2016 Computer Science for All Initiative (CS for All) to the recently released Governors' Compact To Expand K-12 CS Education, we can see that at the policy level, there has been a broad consensus about increasing participation in CS across the U.S. education system, especially in grades K-12. Although more and more resources are allocated to CS, researchers have raised critical questions about whether these initiatives can truly serve women and minorities who have been historically underrepresented in CS [29][30].

In the CS world, the lack of diversity has been a critical problem. According to the National Center for Women & Information Technology, in 2021, only 26% of the computing workforce were women, of whom 7% were Asian American, 3% African American, and 2% Latina [26]. At the university level, 22% of computer science undergraduate majors were female [25]. At the high school level, take California as an example, girls represent only 30% of students enrolled in CS courses, despite comprising nearly 50% of the whole high school population; African American, Latinx or Native American/Alaskan Native students represent only 16% of students enrolled in Advanced Placement (AP) CS classes, compared with 60% overall enrollment [14].

Despite the urgency of addressing underrepresentation in CS, as researchers pointed out, in most cases, underrepresented communities' interests are served only when they are aligned with the political and economic interests of dominant groups [1][18]. As stated in the Governors' Compact, the dominant discourse of CS education has positioned national security, economic competitiveness, and the need for a high-tech workforce as the ultimate goals of expanding access to CS. However, does this align with what youth believe should be the goal of expanding CS learning opportunities? There is a dearth of understanding of what youth from traditionally underrepresented communities believe makes CS education consequential. To add to this understanding, this paper seeks to explore students' own perspectives about what makes consequential CS learning experiences.

2 THEORETICAL FRAMING

2.1 A Justice Stance Toward Equity

In this paper, we take a justice stance toward equity in CS education [3][16][29]. We define equity in CS beyond increasing inclusion and representation of women and Students of Color within the current CS landscape. Putting in question the binary and deficit-oriented perspectives of students, equity scholars have pointed out that the lack of diversity in CS is not because women and Students of Color lack interest or talent in CS, but is the result of compounding factors, including the lack of access to quality CS curriculum, culturally relevant pedagogies, accessible tools, and teacher resources [13][17][22][27]. Moreover, the larger infrastructure of our society has shaped the public's perceptions about who belongs in CS, which has perpetuated racist and sexist stereotypes that push women and Students of Color out of CS [7][21][22][27]. By taking a justice-centered approach to equity, we question the current CS education structure and agenda that have systematically excluded women and Students of Color, with the goal of supporting youth to resist oppression while aiming for transformative CS learning experiences [9][10][27][29]. We believe a justice-centered CS education should promote youth questioning the power and purpose of tech, issues of underrepresentation in the field, and how their perspectives can contribute to positive social change in both schools and society. More specifically, Vakil [29] proposed a justice-centered framework outlining three key topics informing our analyses in this paper:

- (1) Ethics: integrating ethics in the CS curriculum to allow students to critically reflect on the role and the power of computing and technology;
- (2) Identity: developing students' disciplinary and political identities in the CS learning environment while increasing their sense of agency to better human lives with technology;
- (3) Political vision: framing the goals of CS in pursuit of peace and freedom instead of "militarism, occupation, surveillance, and expansionism".

2.2 Consequential Learning

Our examination of students' perspectives about CS learning is also informed by the concept of consequential learning. Consequential learning is an equity-oriented framework that positions students at the center of learning and argues that learning should build on students' own perspectives and what matters to them [2][4][12]. Birmingham and colleagues [2] pointed out that in STEM education, unequal distributions of power can greatly impact non-dominant students' self-efficacy and contribute to their diminishing interest in participation. Consequential learning interrogates the power dynamics within a learning space and centers youth agency, allowing students to take up rightful presence to challenge oppressive ways of teaching and learning within STEM classrooms [4][27]. Offering nondominant students the opportunities to leverage their personal experiences to challenge oppressive systems and

address their community-based concerns is regarded as consequential for non-dominant students' development of identity and agency and their participation in collaboratively reimagining a more equitable world [12]. From this perspective, centering student voices and unpacking students' experiences within CS classrooms will give us a better understanding of what really matters to students who have been historically minoritized in CS, which in turn will inform our practices of reforming CS education for pursuing equity and justice.

3 METHODS & DATA ANALYSIS

This study took place in a large public school district on the west coast, serving 73.5% Latinx, 10.5% White, 8.2% Black, 4.2% Asian, and almost 80% of students receiving free/reduced lunch. We partnered with three teachers across four CS classrooms (i.e., Exploring Computer Science (ECS) and Advanced Placement Computer Science Principles (APCSP)) in three schools. All three teachers we worked with are veteran CS teachers who have been teaching CS in a large urban school district for eight years or more. Through a research-practice partnership — a sustained, mutualistic collaboration across researchers and educators producing original analyses toward the improved use of research in decision making and educational outcomes [6][28] — educators/administrators in the district came together with university researchers to understand, from high school youth's perspectives, how CS learning can be meaningful for all students. Collectively we understand learning as occurring through social activity within larger historical/cultural contexts that impact how students make sense of their learning in the world [31][32]. As such, the larger study involved using interpretive participant observation to collect data sources focused on daily practice, carefully documenting the details of that practice with attention to student-teacher interactions, while seeking to understand what that practice meant to both its participants and observers [8][23]. Data sources from this research-practice partnership include classroom observations, interviews with teachers and students, and pre- and post-surveys.

This paper focuses specifically on interviews conducted longitudinally with 30 students from the time of their first experiences in high school CS courses (during the 2018-19 school year) to up to three years after that experience. Students were interviewed during their first high school experience with CS (either ECS or APCSP) and one to two years later to share their experiences and reflection on CS education. Not all students interviewed in the first year kept in touch, but a total of 30 students were interviewed multiple times over the years. Our goal is to amplify youth perspectives about the consequentiality of CS education by using student interviews to answer the following research questions:

- (1) In retrospect, when students reflect on previous CS learning experiences, which do they articulate as most valuable?
- (2) From students' perspectives, what factors contributed to making those experiences memorable and consequential?

We followed a grounded theory approach [11] to identify themes emerging from our continuous and systematic review of interview data about what counts as and contributed to memorable and consequential CS learning experiences. Our research team employed both “top-down” and “bottom-up” approaches in developing our coding scheme.

Researchers first collectively read through interviews student by student together. During this process, each researcher coded the interviews individually and jotted down potential codes, questions and/or notes in a shared document. After finishing coding for one student, the team would meet and discuss key codes to name and how to define them. Next, researchers paired up, first coding individually and then responding to their partners’ codes, notes, and questions. The team would meet again after finishing coding for one student and discuss edits to the coding scheme. At the same time, we drew upon sociocultural perspectives on learning [20][31], theories of community cultural wealth [33], practice-linked identity [24], and culturally relevant pedagogies [19] to inform our coding scheme. After several rounds of calibration meetings, the team came up with main codes related to students’ most memorable and valuable CS experiences such as “CS talk”, “social justice”, “CS impact”, “pedagogy”, “CS support”, and “teacher relationships”, with subcodes including “CS project”, “CS definition”, “Culturally responsive computing”, “teacher care”.

With the coding scheme, researchers moved forward to code students’ interviews independently. After coding each interview, researchers would write reflections on student perspectives on consequential CS learning in a shared coding memo. This helped us highlight the key experiences and/or features of each student that we could return to for exploring their perspectives more deeply. Following the coding of every three interviews, the team would meet and discuss questions and/or notes emerging from their individual coding process. After the first round of coding, the team took a “bottom-up” approach to review coding scheme and collapse codes to reduce redundancy.

4 FINDINGS

Our initial findings suggest that minoritized youth define the following as consequential for CS learning up to three years after their first high school CS class: 1) freedom for youth to express personal interests, passions, and concerns; 2) opportunities to expand student views of CS and self; and 3) teacher care for students, learning community, and subject matter.

4.1 The freedom to express personal interests, passions, and concerns

CS learning experiences were most memorable for students who could connect class projects to personal interests, passions, and concerns, but “consequentiality” was defined by opportunities to use creative freedom in ways that: 1) demonstrate depth of

knowledge of a specific interest and/or one’s improving CS skills; 2) reflect unique perspectives/styles; and 3) potentially impact a larger community or group.

For example, Linda enthusiastically described her final AP CSP exam “create task”: an app that simulated how quickly an infection can spread through handshakes. This project had multiple purposes. First, it reflected something specific and unique about Linda: she is deeply interested and knowledgeable about the function of viruses and bacteria, and one day she wants to be an epidemiologist remembered for curing a disease. She explained: “I want to make some kind of contribution...I think about all the people who invented different vaccines...I want to do that, I want to be doing that research that helps get an HIV vaccine, or that somehow figures out a way to stop future pandemic coronaviruses.” Additionally, her mother—a biology professor and role model that Linda can “nerd out with”—teaches an activity in her college-level courses in which people act out how quickly a virus spreads by passing popsicle sticks—representing the virus—to one another upon shaking hands. By creating this app, Linda not only had an opportunity to demonstrate her deep knowledge of how epidemics happen—during a COVID pandemic, no less—but she was also excited to create a project that her mother could use with her college students in virtual classrooms. In addition, Linda became deeply engaged with her project when she added her own unique element to the activity: demonstrating how social distancing slows the speed of transmission when people shake hands less often. This was not something that her mother included in the activity, and this added complexity to her algorithm created stress. However, overcoming this challenge made the CS learning more meaningful as Linda explained that the best part of her project was: “figuring out how to make stuff work. It forced me to kind of...look stuff up. I couldn’t do this project just within what I learned in the class...it ended up being way more complicated than I was expecting. I was able to figure it out.” Because of the connections to her personal interests, Linda was motivated to solve difficult problems and find that fulfilling. Furthermore, she acknowledged that in this project, the most challenging aspects also proved to be the most engaging because of her desire to solve problems as they arose. When talking about project highlights, she said: “There were definitely a lot of challenges in this project. Getting the final algorithm to work where I was doing all the [hand] shaking. It turns out to be really complex and doesn’t feel like that when you do it in person. To distill it down to a set of steps is pretty complicated...This random number function was also pretty difficult to develop because ...it would just kind of get stuck in a loop...I had to kind of add these conditions to prevent it from doing that.” Through this experience, Linda noted that she felt CS activities really need to build on students’ passions and interests so that youth can see “that computer science can be expanded beyond the tech industry.”

Carlos similarly found meaningful engagement with computer science when he had the opportunity to connect his AP CSP

create task project to supporting friends experiencing depression during the COVID pandemic. He noted:

“I was really evaluating and going through my thoughts, like what ... Not really been through, but there was a lot of friends—because at this school I didn't really understand what suicide was and all that, I'd heard about it, but I had never really met anyone who had gone through depression—but during high school I had made friends who had been going through some stuff and I guess [they would] tell me about their problems and I would try to help them in the best way, so then what I ended up making was an app that depending on your mood, whichever you picked from, it would give you a quote.”

Carlos wanted to offer people around him with something that could inspire hope, happiness, and motivation to keep going, even when things were tough. He included quotes about how “every moment that you are upset that's a happy moment wasted” or how “when you're stuck you feel like you're getting pulled back [like an arrow], but when you release the arrow, it's going to launch you to something greater.” In this project, CS learning became consequential because his project not only reflected who he is and what he cares about, but also he used it as an opportunity to have a positive impact on his community. He explained that it was important to have “the opportunity of having to show who you are” and that the app reflects how he would “get attached to people that I meet because I really care for them and I really...I guess, hope the best for them and I wish they prosper in life.” And at the same time the app was something he could offer up to his friends as support that reflected his own unique self and how he likes to support friends in times of need. Thus, similar to Linda, Carlos had opportunities to share his knowledge through his app, personalize the app to reflect his connection to people, and design something that could potentially positively impact his friends.

José also experienced consequential CS learning when connecting to his personal passions in ways that demonstrated his understanding of a broader issue, reflected his unique self, and had the potential to impact others around him. More specifically, José programmed a game that teaches players about homelessness and to empathize with the experiences of the homeless. He explained, “in [our city] there's a lot of homelessness...and sometimes we just need to change that, so creating a game that could pull the person [in] and actually be more informed is a good thing, because games can actually be like movies and then influence the player to doing the right thing.” He said he wanted to create a game that could have positive impact, and initially he and his group were considering other topics to focus on (e.g., clean water and water supply issues, etc.). However, they came to realize that working specifically on something like water would only solve that one issue, but focusing on a larger issue like poverty could lead to change in a whole range of other problems related to not only water and pollution, but also homelessness, jobs, etc. So José

created a game with his team that educated people while also being something that he could make his own style.

Importantly, youth were not moved by superficial opportunities to personalize projects (such as choosing the colors for a website or an area of focus alone). As Kristian explained when reflecting on his CS experiences 3-4 years later, the most consequential CS projects were those where he not only had creative freedom to design the project, but could demonstrate his problem solving and success at learning to program that helped him “fe[el] really good about myself.” Also thinking about how his project (that taught people Mandarin, French, etc.) could “help someone else” was key to consequentiality. This was also true for Katalia who felt that experiencing success and being able to demonstrate her learning in conjunction with creative self-expression is “what carried me to continue going” and find meaning in the CS classroom. In these ways, youth articulated how the freedom to express personal interests, passions, and concerns was essential to consequential CS learning experiences when they connected to demonstrating one's knowledge of a subject and CS growth while potentially contributing to improving other peoples' lives.

4.2 Opportunities for youth to expand their views of CS and self in the world

Youth articulated that one of the most memorable aspects of learning CS was its impact on personal values and definitions of CS. For example, three years after José took his first CS class, he recalled how important it was to realize that CS is everywhere. He noted that learning CS is like learning a world language with which “...you could build almost anything.” As a result, José expressed an eagerness to pursue CS in higher education.

However, consequentiality of CS learning did not only result in youth wanting to be computer scientists. For Maria and Karla, CS learning that shifted their critical awareness of computing was incredibly meaningful, even if they were not initially drawn to CS or want to pursue it beyond high school. Maria shared that she was a reluctant learner at first, and “not really interested” in taking CS. Similarly, Karla took CS in 9th grade but declined a teacher's recommendation to take AP CSP. However, Maria noted, “I'm glad I was made to take it, I think, it was valuable” and acknowledged that “exploring all the different aspects of CS” was something everyone should experience. This was because both Karla and Maria found that discussing CS ethical issues in ECS classrooms gave rise to their critical awareness of the positive and negative impacts of technology. Maria defined CS as a “combination of knowing how computers run and being able to explain how and why code works.” She added that understanding the “qualitative aspects of computing and algorithms and the cultural, societal and economic impacts on different communities” are important components of her understanding of CS and views of the world, and learning how biases in tech can impact society was meaningful to her. Likewise, Karla shared how powerful it was to realize that CS is more than “just coding” or “a bunch of numbers,” but can

also create “a lot of [bad] things.” Awareness of CS’s impact on her views of the world shaped her educational experience.

Anna also described how learning CS expanded her notions of CS and self in the world, serving as a form of cultural capital in college even though she wasn’t a CS major. She noticed that taking a high school CS course “really opened my eyes, like everything around us has to do with coding.” In her first year of college, Anna noticed many of her peers are majoring in CS or Data Science. As a humanities major, her peers assumed she didn’t have a working CS knowledge base. However, Anna was able to “blend in” because “I can add to the conversations, even though my major isn’t CS” by having conversations about programming or supporting peers in their CS projects. Her CS learning became consequential as a resource for entry into multiple communities, even though she wasn’t majoring in CS.

Learning became consequential for students when they developed new understandings of CS that transformed their views of the world and could be used to impact their participation in their communities. We also noticed trends in how students’ initial reluctance to engage with CS concepts transitioned into unequivocal endorsement for all students to experience CS in high school because, as Maria explained, “I think everyone should have the chance to take a CS class... you can approach technology in a different and more educated way.”

4.3 Teacher care for students, learning community, and subject matter

“Teacher care” also emerged as a part of how youth defined consequential CS learning, particularly in interviews conducted three years after youth first experienced a CS class. This was specifically true for youth enrolled in Ms. Martinez’s CS classroom, and she was named as central to students’ best memories of high school CS. Through the example of Ms. Martinez, we identified three layers of caring behaviors, which worked together to construct profound and meaningful CS experiences for students. They are teacher care for 1) individual students, 2) learning community, and 3) subject matter.

First and foremost, Ms. Martinez saw each of her students as a whole person. Her care for individual students transcended beyond physical classroom boundaries and time. To be specific, Ms. Martinez viewed learning as a process, and Anna shared that what she found really helpful in Ms. Martinez’s class was that she would make enough time and provide personalized support for students to fully understand the content. For example, after evaluating students’ coding projects on Scratch, Ms. Martinez would adjust her lesson plan and create activities to help students understand challenging concepts. Moreover, Ms. Martinez regularly created additional opportunities for youth to learn beyond class time. As Reena shared, Ms. Martinez offered additional tutoring sessions afterschool and on weekends to help students figure out questions and prepare for AP tests, and she also opened her classroom for youth to do other school work or just hang out together. Students could see that Ms. Martinez

cared deeply for their learning in the ways she devoted her own time and energy to every one of them. Teacher care was the highlight of Reena’s high school CS experience and the inspiration for her growing interest in CS, as she shared with us two years later. Furthermore, for Karla, teacher care was visible when Ms. Martinez gave her a robot kit to use at home, giving her the freedom to explore how to set it up herself while making sure that she was there for any questions Karla may have. Ms. Martinez showed Karla that she trusted her, and also wanted to support her learning and growth beyond the classroom. Reena described how she and others were “really considering becoming a computer science major...A lot of my friends [in] that class are being computer science majors” because of the ways Ms. Martinez “really kept us going a lot.” Ms. Martinez also learned about what youth cared about through her teacher relationships with youth, then connected CS learning to what was happening in the real world related to those interests by taking students on field trips and creating opportunities to allow students to know more about how people work with CS in real life.

Apart from one-on-one relationships with students, Ms. Martinez also successfully built a community of support in her CS class which created a feeling of respect and love across the community. As Carlos noted, to make sure that every student had access to a computer, Ms. Martinez would try her best to find spare ones and let students take home to do work. He shared, “In my whole school career, I’ve never seen any teacher do that. I felt like it was amazing to see a teacher actually go out of her way and just provide that extra support and help her students.” Under Ms. Martinez’s influence, Carlos later started a group chat for his CS class where his peers showed each other emotional support and checked in on each other’s CS projects, which helped a lot especially during quarantine. Reena also pointed out that it was the supportive and loving class environment that really helped her pass the AP exam and make lifetime friends. We can see that Ms. Martinez’s care for the whole learning community nurtured a culture within CS classroom that encouraged and sustained mutual support and love, which in turn benefited all in this community.

We also found that teacher care for the subject matter played a critical role in making CS learning consequential for youth. For example, what has stuck with Rafael and influenced him the most three years after his first CS class was Ms. Martinez’s passion toward teaching. He noted: “If someone is so passionate about something and can teach something that she loves to do, I would want to try that.” He further shared that it was Ms. Martinez’s passion that transformed his class into a small community in which everyone shared the same passion toward learning more about CS. This experience further grew his interest in following Ms. Martinez’s steps to pursue a teaching position in future to influence more people as their role model.

The profound impact of teacher care on shaping youth’s CS learning experiences was also described by one student’s sharing of a different teacher whose lack of care had detrimental

consequences. Karla took ECS and Game Design in her first two years of high school with Ms. Martinez in a positive and nurturing environment that made her want to major in CS in college. However, Karla's experience with a different AP CSA teacher in senior year made her want to take a break from CS. Karla shared that her AP CSA teacher was neither able nor willing to care for her students. Because of her medical conditions, the teacher barely showed up for class or tutoring sessions, and when she was present, "she was very quiet and she just didn't sound like she wanted to be there at all." Karla was most frustrated when no one listened to their needs:

"I was sitting there and I didn't fully understand one of the learning targets. I want to be taught how to do this. I told her and she just completely left me behind. She was just like 'We have to move on.' Since she didn't care, it was easy for me to not care, and I mean at the end of the day, I thought of it as like 'Oh I'm getting an extra hour of sleep, when she doesn't have class.' So I didn't see it as like I'm losing an hour of knowledge, like I'm just losing an hour or I'm gaining an hour of sleep."

Disappointed by this experience, Karla gave up on the idea of becoming a CS major and took a different journey in college. By presenting Ms. Martinez and Karla's story together, we do not mean that every teacher should sacrifice their personal time and make extra efforts to care for their students. Rather, we want to highlight how students' definitions of consequential CS learning center teacher care in shaping students' academic and career interests, perspectives, and life decisions.

5 DISCUSSION & CONCLUSION

5.1 Student's development of disciplinary and political identities in CS

As Vakil [29] addressed in the justice-centered framework for CS education, the design of learning environments needs to support students' development of multiple identities, including disciplinary, civic, and political identities. Our findings validate this argument by showing that students value having the freedom to show who they are and what they care about in their community through their CS projects. Linda, Carlos, José, Kristian, and Katalia's voices describe how CS learning became consequential when they could make personalized CS contributions to a larger movement or purpose for positive social impact. As Vakil [29] pointed out, CS education is not neutral but already politicized. Thus, it is particularly important for minoritized youth to shape the world with CS. We need their social justice perspectives to shatter the illusion of "a neutral world" from the dominant discourse in CS to reimagine a more justice-centered world with computing, and this can happen most effectively when ensuring that youth are given creative freedom to express the depth of their knowledge and CS learning in ways that potentially impact the larger community with their voices and styles.

5.2 Teacher as the agent for consequential learning

From students' stories, we can see that teachers played a critical role in creating a supportive and loving environment. Our findings highlighted teacher care for individual students, learning community, and subject matter as key factors which shaped students' positive experiences with CS learning and helped develop their academic and career interests in CS. It is noteworthy that Ms. Martinez's caring behaviors not only influenced how students were engaged in CS learning, but also modeled how to care for other people which is consequential for youth both within and beyond CS learning. The group chat created by Carlos during quarantine and Rafael's envisioning himself as a teacher to influence more people as his teacher did demonstrated that Ms. Martinez's care for students was transformative because it motivated her students to develop their agency in caring for peers and supporting others. In this way, Ms. Martinez allowed us to see how empowering teacher care can be, which facilitated consequential CS learning by creating a supportive culture within CS class and developed students' own identities as supporters and role models for others.

5.3 A critical lens to approach, define, and evaluate CS

We found that there was unanimous agreement among students that CS learning is valuable and should be accessible to all. Regardless of whether they pursued CS beyond high school or not, the critical lens toward how students approach, define, and evaluate CS turned out to be consequential for them. The definitions of CS given by José, Maria, and Karla reflected their critical awareness of the all-around presence of CS and its transformative impact on our daily lives. Moreover, Anna's story of realizing and leveraging her CS knowledge as cultural capital to participate in conversations with CS majors in college again support Vakil's [29] argument that students should develop political identities in CS learning: Anna's critical awareness and CS knowledge enabled her to challenge the dominant discourse marginalizing women and minorities in CS and larger sociopolitical agendas as she inserted herself in a space where she was not initially valued as a possible contributor.

Prioritizing the perspectives of minoritized youth, our findings have significant implications for the broader "CS for All" movement and efforts to increase diversity in computing: CS education must move beyond fulfilling only the political and economic desires of those in power, toward centering the personal interests, needs, and agency of minoritized communities if we are truly to see increased diversity in the field toward a more just world.

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