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RESEARCH ARTICLE

Student Agency in a High School Computer Science Course

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Abstract

This study explores student agency in the context of a culturally authentic computer science (CS) curriculum implemented in an introductory CS course in two high schools. Drawing on focus group and interview data, the study utilizes qualitative research methods to examine how students exercise critical agency as they engage in the course and how the curriculum supports student agency. Findings suggest three ways in which the curriculum served as a context for student agency: (1) gaining CS knowledge and skills that students then apply to address real-world needs and problems, (2) creating opportunities to "try-on" or improvise new identities and/or envision "future selves" in CS, and (3) engaging in personally relevant project work that leverages assets students brought to their experience with the curriculum. Implications for CS education research and practice are discussed.

Keywords High school computer science · K-12 computer science · Culturally authentic pedagogy · Student agency

In spite of the prevalence of technology in every corner of our lives and an ever-increasing demand for computer scientists (Bureau of Labor Statistics, 2021), few high school students opt to study computer science (CS), with women and students of color acutely underrepresented in CS classrooms (Ryoo et al., 2013). In 2017, only 19% of bachelor's degrees in CS were awarded to women, and only 10% and 8% were awarded to Hispanic and Black students, respectively (National Science Board Report, 2020). Students who do enroll in foundational CS courses often find that courses focus on rudimentary skills (Margolis et al., 2008) and fail to offer culturally authentic experiences that allow them to incorporate their perspectives and lived experiences (Ryoo et al., 2013).

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The CAPACiTY curriculum was developed to provide an engaging introductory CS course designed to encourage girls and minoritized students to pursue CS. The Introduction to Digital Technology (IDT) course is the first course in most of the high school Career, Technical, and Agricultural Education (CTAE) Information Technology (IT) pathways in Georgia, including the CS and Programming pathways. This introductory course represents a critical juncture in students' progression in the pathway, as performance in IDT directly influences subsequent CS course-taking patterns. By focusing on increasing the appeal to the IDT course to diverse students, curriculum designers sought to address the overarching goal of the CAPACiTY project: to increase the presence of girls and minoritized students in later courses within the CS pathway, especially Advanced Placement (AP) CS courses.

Key elements of the curriculum include an inquiry-driven, collaborative, project-based learning (PBL) approach and the inclusion of culturally authentic practices (CAPs). The curriculum encourages agency as students bring personal interests and experiences to bear on their selection of a topic to research and incorporate into a series of work products including a narrated PowerPoint presentation, a website, digitally produced music to accompany the presentation and website, and an app-based game.

The current study focuses specifically on developing an understanding of how students build and exercise critical agency through engagement with the CAPACiTY curriculum. The study is guided by the following research questions:

1) How do students exercise agency as they engage with the CAPACiTY curriculum?
2) To what degree and in what ways does the CAPACiTY curriculum support student agency?

Background Literature

In the following overview of relevant literature, we briefly discuss student agency and how it has been defined in previous scholarship and pursued in the context of computer science education. We then turn to a discussion of previous research on critical agency in STEM education that serves as a basis for our exploration of critical agency in a CS education context.

Scholars define agency in various ways, including as the act of making choices about how to approach work; accepting, resisting, or taking liberty with assigned tasks (Olitsky, 2006); making sense of connections with material; and taking responsibility for the goals and outcomes of their learning (Reeve & Tseng, 2011). Agency is generally conceptualized as an active process rather than a personal characteristic or attribute (Priestley et al., 2015). Holland and colleagues (2001) see agency as connecting the actions of individuals or groups to a sense of purpose, with the objective of creating, impacting, or transforming themselves or the conditions of their lives. In their conceptualization of student agency, Rector-Aranda and Raider-Roth (2015) emphasize the complexity of student agency and how it represents "an interrelated web made up of student motivation, engagement and voice that creates the essential whole" (p. 3).

The CS education status quo too often limits student agency, in that CS courses often focus on learning specific software, tools, and programming languages in ways that students find boring or unrelatable (Margolis et al., 2008). Student agency can be leveraged to remedy this lack of relevance, as Ryoo and colleagues (2013) state, "learning experiences – especially for youth who have been previously disengaged from scientific fields – are enhanced when a relationship is established between learning the science, connecting to a larger social purpose, and developing personal agency" (p. 164). Margolis and colleagues (2008) sought to provide such learning experiences in their Exploring Computer Science (ECS) curriculum, which exposes high-school students to a range of CS topics through hands-on, culturally relevant instruction. The ECS curriculum, described as "computing with a purpose" (Margolis & Fisher, 2002, p. 49), seeks to build on students' interests in technology by contextualizing CS skills within issues students find important. The collaborative, hands-on projects and development of CS communities of practice help cultivate students' practice-linked identities as *doers of CS* (Nasir & Hand, 2008).

Critical agency, a concept explored in science, math, and engineering education (e.g., Basu et al., 2009; Godwin & Potvin, 2017; Godwin et al., 2016; Turner & Font, 2007), expands on notions of student agency by providing opportunities to enact change through a critical mindset and STEM (science, technology, engineering, and math) knowledge. In their work in science contexts, Basu and colleagues (2009) describe three central features of critical agency:

1) Students gaining deep understanding of science and the processes, skills, and modes of inquiry associated with science
2) Students identifying themselves as experts in one or more realms associated with science, and
3) Students using science as a context for change, such that their identity develops, their position in the world advances, and/or they alter the world towards what they envision as more just (p. 346).

Additionally, some scholars have argued that developing critical agency requires interaction among students as they develop a "subject matter community" (Schenkel & Calabrese Barton, 2020, p.355). One study of middle-school students captures how group work amplified students' collective efforts to enact changes in their classroom community as students were given agency to identify, research, and generate solutions for a problem of their choice (Schenkel & Calabrese Barton, 2020). For example, one group observed that not all students' achievements were recognized equally and designed an accomplishment board using circuits to highlight the achievements of their classmates.

The development of critical science agency has also been documented in informal STEM settings. For example, in their critical ethnographic study of low-income, middle-school-aged youth, Barton and Tan described the development of critical science agency among participants in a summer program (2010). Youth in the program studied green energy issues in urban contexts, developed knowledge of information technologies, and created documentaries conveying their understanding of the phenomena of urban heat islands. In creating and presenting their documentaries, students positioned themselves as experts, both on scientific and community issues. Barton and Tan (2010) argue that the youth were thereby able to challenge existing stereotypes of low-income, minority youth being disinterested in science. In this way, the program fostered critical science agency by inviting youth to use their expertise to engage their community in an issue that was important to them in a manner that challenges common notions of who and how one "does" science.

Attending to student identity and agency in high school may influence students' decisions about continuing in STEM fields (Godwin & Potvin, 2017). In a longitudinal case study, Godwin and Potvin (2017) followed one student during high school and into college. The authors found that developing strong subject identities in mathematics and science, and exercising agency through high school science, empowered the student to major in engineering (Godwin & Potvin, 2017). Ultimately, this student left the engineering major, citing changing perceptions of engineering structures and practices that gradually "chipped away" at the critical agency cultivated during her high school years (Godwin & Potvin, 2017). These findings warrant further exploration of the potential long-term benefits of providing high-school students with opportunities to develop critical agency in STEM.

Although there is limited research on critical CS agency, related concepts have been explored in CS contexts. The concept of critical computational literacy is similar to critical agency in that it draws on the fields of critical literacy and computational thinking to describe a process for addressing social injustice using processes and tools common in CS (Lee & Soep, 2016). Lee and Soep (2016) sought to understand critical computational literacy in their work with high-school students participating in a youth radio internship program. The authors studied how students worked collaboratively with college-aged mentors and the authors themselves to design an interactive website and write a radio article describing the economic, historical, and social impact of gentrification within their community. Qualitative findings illustrated the development of students' sense of agency to affect change within their community using computational thinking and tools. Specifically, through the project students demonstrated their knowledge of computational tools and platforms and the ways in which they could strategically use these tools to share their message effectively with a broad audience. Though Lee and Soep (2016) do not explicitly connect critical computational literacy to previous work on critical STEM agency, this study offers an example of the ways in which critical agency can be fostered in a CS context.

While studies on critical agency in CS remain scarce, we see possibilities for further exploration based on the promising findings of related studies on critical STEM agency and interventions to promote student agency in CS. Additionally, we acknowledge a related body of work on the development of CS and STEM identities through culturally relevant and asset-based pedagogies (e.g., Tzou et al., 2019; Wanzer et al., 2020). We hope to build upon this literature to explore critical CS agency, which we theorize to be a collective process in which students gain CS knowledge and skills, come to identify themselves as experts in CS, and, in the process of CS identity development, see and use CS as a mechanism for change.

Methods

This study represents one strand of a broader program of applied research examining the implementation and outcomes of the CAPACiTY curriculum as it was introduced in high school CS classrooms. Below, we contextualize the study by first describing the curriculum and its foundations followed by descriptions of the setting, data sources, and data analysis.

The CAPACiTY Framework and Curriculum

The CAPACiTY curriculum is comprised of four units intended to span the year-long IDT course. The units, described in Table 1, build upon one another as students choose a focal problem to study, form teams based on shared interests, create and share digital artifacts, and apply the technical skills needed to complete each task. Each unit is structured as a separate PBL lesson, but all are completed in service to the focal problem.

Central to the curriculum framework is the use of PBL pedagogical strategies to foster mastery of computational thinking concepts and practices through research-based culturally authentic practices (CAPs). The design of CAPs activities was informed by best practices from culturally relevant education frameworks (Dover, 2009; Gay, 2010; Ladson-Billings, 1994), asset-based pedagogy (Esteban-Guitart & Moll, 2014; Lopez, 2017), self-determination theory (Ryan & Deci, 2000), and stereotype threat interventions (Steele et al., 2002). In general, CAPS activities focus on the four interrelated goals of (1) building agency; (2) promoting asset-based thinking and sense of belonging; (3) reducing social identity/stereotype threat; and (4) building equity through collaborative work. These highly scaffolded CAPs activities, embedded throughout the curriculum, attend to the cultural and social needs of marginalized students by nurturing students' choice, voice, and identity in the classroom. PBL principles incorporated into the framework focus on strategies that promote deep student engagement and learning, namely enabling exploration, promoting understanding of content through sustained inquiry, encouraging authentic engagement with challenging real-life problems, and promoting reflection, discussion, and collaboration (Bransford et al., 1999).

As illustrated in Table 2, multiple activities embedded throughout the curriculum are designed to promote the three features of critical agency described above. Most importantly, students pose their own problems, research existing solutions to the problem, and suggest new solutions to the problem. Teachers encourage students to define their own narrative, addressing the problem from a story-telling perspective and bringing their lived experiences into the project. Throughout this year-long project, students are challenged to persuade others about the

Table 1 Overview of CAPACiTY curriculum

Unit	Unit overview	Digital product
Unit 1: 4 weeks	Students work in pairs to choose a problem on which to focus their work and to develop a narrated PowerPoint presentation intended to inform the audience about their selected problem. This work requires that students conduct background research on their problem and promotes the development of a culture of teamwork and collaboration	Narrated Slide Deck
Unit 2: 6 weeks	Students merge into groups of four based on common interests, settle on their focal problem to be used for the year, and develop a website to both raise awareness about their focal problem and motivate website users to engage in helping to address the problem	Website
Unit 3: 6 weeks	Students explore algorithms and other computer programming concepts within the digital music creation platform EarSketch, which allows users to create new musical compositions by mixing musical stems using Python or Javascript programming languages. Students use this program to create two pieces of music to accompany, and increase engagement with, their previously created PowerPoint presentation and website	Coded Music for Website
Unit 4: 7 weeks	Students explore game design, as well as additional computer programming content, culminating in their use of App Inventor to design an app-based game. The game is intended to increase awareness of and represent potential solutions to their focal problem	Mobile App

Table 2 Critical agency components in the CAPACiTY curriculum

Critical agency component	Means of achieving critical agency component
Students gain a deep understanding of computing and the processes, skills and modes of inquiry associated with computing	Computational thinking concepts and practices • Design • Problem/Product Decomposition • Pattern Recognition • Algorithms • Programming • Debugging • Abstraction • Networks and the Internet • Impacts of Computing
Students identify themselves as experts in one or more realms associated with computing	Culturally authentic practices embedded in course • Promoting asset-based thinking and sense of belonging • Building equity through collaborative work • Building Agency • Reducing social identity/stereotype threat
Students use computing as a context for change, such that their identity develops, their position in the world advances, and/or they alter the world towards what they envision as more just	Project/problem-based learning pedagogy Curriculum promotes student's voice and choice through the use of PBL teaching strategies. Students using the ***** curriculum: • Pose a problem or question that is personally relevant • Engage in sustained inquiry to increase awareness of the problem and to explore solutions • Pose questions, find online resources, conduct interviews with stakeholders and analyze previous solutions • Engage in reflections, critiquing of others, and iterative revisions to their products • Actively reflect on the process and what they have learned as they create a personal portfolio and resume • Produce digital products meant to promote change • Present their products publicly to an appropriate authentic audience

importance of the problem, first through voice narration in their PowerPoint presentations, then through websites incorporating their personal perspectives, and lastly by creating computational music with emotional intent. Additionally, the curriculum directs students to adopt real-life professional roles, such as Project Manager, Server Administrator, Quality Assessment Manager, and Layout Designer, and to rotate these roles to ensure equity. In addition to project work, the curriculum addresses agency through supplemental activities including an ongoing resume-building exercise that highlights students' technical accomplishments, learning gains, and skill acquisition. In a curriculum component designed to counter stereotype threat, students view video profiles in which diverse undergraduate CS majors describe their college experiences, decisions to pursue CS, and career aspirations.

The CAPACiTY Theory of Change model (Fig. 1), based broadly on work by Appleton and colleagues (2008), posits that improvement in autonomy, competence, and belonging leads to increased student engagement and, ultimately, improved student outcomes such as increased student learning of CS skills and more students continuing to take CS courses. Prior research suggests that focusing on these pedagogical principles, both in the scaffolded curriculum materials and in teacher professional development workshops, should lead to changes in classroom practices that better enable students to experience a sense of autonomy, competence, and belonging in their CS classroom (Deci & Ryan, 2008). The research presented in this paper addresses the question of whether students in the CAPACiTY IDT course develop the necessary critical agency hypothesized in the Theory of Change.

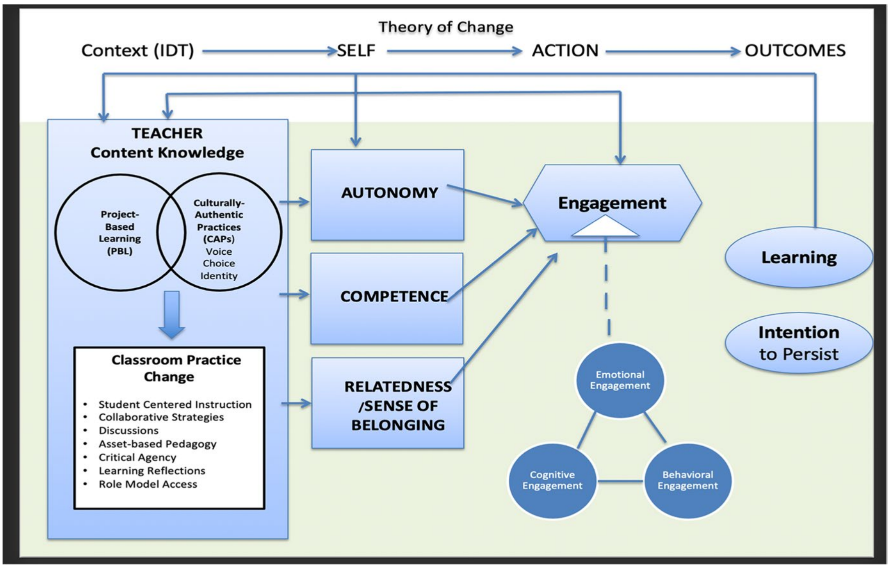


Fig. 1 CAPACiTY theory of change

Setting

During the school year in which data were collected, the CAPACiTY curriculum was implemented in two schools, Dogwood High School and Riverbend High School (pseudonyms), both located in suburbs of a major city in the southeastern United States. Both Dogwood and Riverbend are located in large school districts and serve student populations of approximately 2,600 and 1,700 students, respectively. Student demographics at both schools are relatively diverse. At Dogwood, Hispanic (44%) and Black (38%) students make up the majority of the student population, with an additional 10% of students identifying as Asian, 6% identifying as White, and 3% identifying as multiracial. At Riverbend, Hispanic students make up 37% of the school population, followed by White (31%), Black (26%), Asian (3%), and multiracial students (3%). At Dogwood, 75% of students are from low-income families as are 38% of Riverbend students. Dogwood reports a graduation rate (75%) and average SAT scores just below the state average. Riverbend reports higher student achievement levels, with a graduation rate (92%) and average SAT scores just above the state average.

One CS teacher in each school implemented the CAPACiTY curriculum in their IDT course. The two teachers, Patricia and Susan (pseudonyms), participated in professional learning activities conducted by the project's curriculum development team. These activities included a summer professional development institute where teachers received guidance on implementing the curriculum and attended workshop sessions on relevant aspects of PBL and culturally relevant pedagogy. Both teachers brought previous experience teaching CS and the IDT course. However, they varied in their experience with the CAPACiTY curriculum. Susan had implemented a previous iteration of the curriculum the prior school year, whereas Patricia was implementing CAPACiTY for the first time. Both teachers taught the curriculum in multiple IDT class periods throughout the school day.

Participants

A total of 204 students participated in the project. This sample includes all students in both teachers' classes for whom consent documents and any study data were collected. Demographics of participating students were generally representative of the demographics at each school. Although the IDT course is intended to be taken in 9th or 10th grade as the first course in the state's CS pathway, both schools also enrolled 11th and 12th graders in the course.

Student Interviews and Focus Groups

Interview and focus group data were collected from a sub-sample of 85 students, representing approximately 42% of all students who participated in the curriculum. Individual interviews were conducted with 28 students and 57 students participated in one of 18 focus group discussions. A total of 14 interviews and 12 focus groups were conducted at Dogwood and 14 interviews and six focus groups were conducted at Riverbend. Sampling for interviews and focus groups included students in each class period taught by each of the participating teachers. As the curriculum was intended to be a foundational CS experience for 9th- and 10th-grade students, students in these grade levels were prioritized for interviews. Additionally, to the extent possible, a balance of male and female students was selected for interviews. Focus groups generally included 3–6 students and whenever possible were comprised of students who worked together as a collaborative group in class. Thus, focus groups tended to be mixed with regard to students' genders and grade levels. Table 3 presents the distribution of students who participated in focus groups and interviews by grade level and gender.

Student interviews and focus groups followed a semi-structured protocol that prompted students to share their perspectives on the curriculum. Additionally, the protocol included items related to particular components of the curriculum and its goals, such as collaboration, relevance to students' lives, students' intention to enroll in additional CS courses, and connections between the course and students' career plans. Excerpts of the interview and focus group protocols are presented in Table 4. Individual interviews typically lasted 20 min and focus groups 45 min.

All interviews were conducted by one of three members of the research team who, while generally familiar with the curriculum, were not directly involved in its development. Interviews and focus groups were audio-recorded and transcribed for analysis.

Table 3 Interview and focus group participants by school

		School	
		Dogwood	Riverbend
Interviews	Grade level		
	9th	11	11
	10th	3	2
	11th	0	1
	12th	0	0
	Gender		
	Female	7	5
	Male	7	9
	Total interview participants (*n*)	14	14
Focus groups	Grade level		
	9th	9	21
	10th	11	4
	11th	6	0
	12th	6	0
	Gender		
	Female	12	8
	Male	20	17
	Total focus group participants (*n*)	32	25

Table 4 Excerpt from student interview and focus group protocols

Topic	Interview/focus group questions
Curriculum perspective	Please tell us what you think about the IDT course this spring • What do you think about the activities you've been working on in the IDT course? - How does the IDT course compare to your experience in other classes? What are the similarities and differences? - What was confusing? Difficult? - What did you enjoy most? What do you like most about the IDT course? - What did you enjoy the least? • What do you think about the EarSketch project in this class? - What did you like about it, and what did you dislike about it? - What do you think about teaching students coding through music? • What do you think about the App Inventor project in this class? - What did you like about it, and what did you dislike about it? - What do you think about the App Inventor software and learning how to code a game?
Curriculum relevance	How does the IDT course relate to your life outside of school? Let's talk about how you decided to focus your project on (topic) • Where did you get the idea for this project? • What about this topic interested you? • Do you think people you know would find these topics interesting or relevant to their lives? Have you shared your ideas about the project with family or friends? • Did your project topic(s) connect to your life outside the classroom in any way?
CS skills and group work	You did several different projects in this class • What skills did you learn throughout your work on these projects? • How do you feel about group work that you did in your IDT course? • Your project team had multiple roles that each group member got to experience. Which role or roles did you like most?
CS identity and career paths	Do you remember your teacher showing you videos from some undergraduate computer science students? (if yes) • What did you think of these videos? • Did you learn anything interesting or unexpected from watching these videos? • Was there a specific student's story from the videos that stood out to you? Do you see yourself as a coder? Why or why not? Are you planning to take additional computer science courses? Why or why not?

Document Data

Student work products were reviewed as a secondary data source to identify instances in which engagement with the curriculum supported critical agency. Work products included the PowerPoint presentations, websites, and games students developed as they worked through each unit of the curriculum. A total of 123 presentations, 71 websites, and 61 games were reviewed.

Data Analysis

Following transcription, interview and focus group data were subjected to sequential qualitative analysis (Miles et al., 2018). All focus groups and interviews were coded by the research team using the NVIVO software program, with the primary goals of developing understanding of students' experiences with the curriculum and identifying evidence illustrative of the various dimensions of critical CS agency. During a preliminary round of coding, the research team met frequently to refine the codebook. Refinements included adding, combining, or revising codes and code definitions to capture, as precisely as possible, the most meaningful aspects of students' experiences with the curriculum. Table 5 presents an excerpt of the final codebook. Once the codebook was developed, three members of the research team coded a common set of six interviews and four focus groups. Coders met after coding the first half of this common data to discuss any coding challenges, resolve disagreements in coding, and address any ambiguities in code definitions, after which the group was able to achieve 0.90 inter-coder reliability for the common dataset. The remaining interviews and focus groups were then divided among the coders.

Coded interview and focus group data were analyzed using either content-analytic summary tables or contrast tables (Miles et al., 2018). Content-analytic summary tables are matrix displays that bring together related data from multiple cases to facilitate exploratory analysis. In this study, tables used to synthesize evidence related to agency included rows with aspects of agency drawn from the literature and columns designating evidence pertaining to individual, group, and/or whole-class experiences. Cells within this matrix were then filled in to contain short statements summarizing the data and notes on the frequency of occurrence within the dataset.

Analysis of document data was intended to provide further evidence of students' agentic work (Research Question 1) and helped illuminate whether and how the curriculum supported student agency (Research Question 2). To that end, work products were reviewed to assess students' overall engagement with curriculum activities intended to promote agency and to identify illustrative examples of student work indicative of agency. Specifically, in alignment with the dimensions of critical agency identified above, the document review sought to identify instances in which students demonstrated proficiency with CS practices, identified as CS experts, and/or used CS in an attempt to create positive change in their own lives and communities. Additionally, by triangulating individual and group student products with a focus group and interview data, we sought to identify instances where student investment in topics corresponded with the degree of completion and quality of the websites and games students created.

Table 5 Excerpt from codebook

Codes/sub-codes		Code definitions
Agency	Building agency (+)	Students' sense that they can, through their actions, effect some change in others or impact a situation • Discussion of projects/activities enabling students to learn, educate and advocate around a specific issue • Discussion of whether and how student projects can inform or influence an audience beyond the IDT class
	Agency CS	Instances of students demonstrating mastery of CS knowledge and skills that can be applied to effect change
	Agency expertise	Instances of students identifying as CS experts, including identifying as a "coder."
	Agency change	Instances of students describing using CS generally or their particular CS projects to effect change in the world or in their own lives/communities
	Building agency (-)	Discussion of instances where student agency was limited in some way • References to missed opportunities for projects to effect change • References to ways in which implementation of PBL limited students' ability to learn, educate, or advocate around an issue
Asset-Based Thinking	Asset-based thinking (+)	Focus on the skills, knowledge, perspectives and strengths present in students, their groups and communities. Code to one of the following:
	Assets brought	References to skills, knowledge, perspectives, and strengths students *bring* to the IDT class
	Assets gained	References to students using skills, knowledge, perspectives students *gain* through participating in IDT
	Asset-based thinking (-)	References to instances where the use of students' prior skills/knowledge/strengths/skills was discouraged Instances of deficit-thinking, focusing on students' weaknesses, learning challenges, etc
Relevance		Discussion of the relevance of the course to students' lives
	Relevance (+)	Instances where students connect course activities to their lives outside of school
	Relevance (-)	Instances where students report that activities were NOT relevant to their lives outside of school

Table 5 (continued)

Codes/sub-codes		Code definitions
Career path		References to student career plans. Code to one of the following:
	Computer science career	Student reports possible interest in pursuing computer science career. Teacher descriptions of how course may foster interest in computer science careers
	Music technology	Student reports interest in music technology
	Non-STEM career	Student reports interest in non-STEM career
	Other STEM careers	Student reports interest in STEM career (outside of computer science)
CS course taking		Student discussion of their decision to take IDT and their decision-making about taking other computer science courses in the future. Code to the following:
	Course comparison	Student makes a comparison between IDT and other courses
	Future CS courses—no	Student reports that they do NOT plan to take CS courses in the future
	Future CS courses—yes	Student reports that they plan to take CS courses in the future

Results

Findings for each research question are presented below. First, we describe the results of our analysis of the ways in which students exercised agency (Research Question 1). Next, we summarize findings illustrating features of the curriculum that influenced the exercise of student agency (Research Question 2).

Research Question 1: Evidence of Student Agency

Based on Basu and Barton's framework defining critical science agency (Basu & Barton, 2010; Basu et al., 2009), our analysis of student agency focused on whether and to what extent students used CS for personal or societal change such that their identity develops, their position in the world advances, and/or their project work attempts to alter the world towards what they envision as more just. Consistent with this framework and previous findings in science education contexts, our data suggest three ways in which CAPACiTY served as a context for student agency: (1) gaining CS knowledge and skills that students then apply to address real-world needs and problems, (2) creating opportunities to "try-on" or improvise new identities and/or envision "future selves" in CS, and (3) engaging in personally relevant project work that leverages assets students brought to their experience with the curriculum. Findings in each of these areas are described below with additional illustrative quotations provided in Table 6.

Gaining and Applying CS Knowledge and Skills

Students consistently reported gaining new CS knowledge and skills as they completed their projects. This was true for students with a range of previous CS experiences, suggesting that the course allowed students to develop new understandings, whether they had previous CS experience or whether CAPACiTY was their first introduction to CS. Students cited specific skills they learned, including HTML, CSS, and website design.

In addition to gaining knowledge and skills specific to CS, students described gains in their collaboration, critical thinking, leadership, and communication skills. One student stated that their favorite part of the course was "teamwork—it's just given us a great life lesson on working with each other. Communicating with people you don't know."

As they detailed their collaborative work, a number of student groups discussed the goal of their projects in terms of reaching a certain audience or increasing awareness about their topic. In one focus group, one student affirmed that their chosen topic, issues with school buses running late, felt meaningful to them "because I feel like it gives other people a voice. It's explaining a problem" and another student commented on the group's shared experience and collective effort to raise awareness: "It's like the problem that we're all having, we have a voice and we can outcast together." Students also discussed how their approach to researching their topics and

Table 6 Students exercise critical cs agency: illustrative quotations

Finding *Students exercise critical agency when they…*	Examples	Illustrative quotations
Gain and apply CS knowledge and skills	Gains in CS technical knowledge and skills	*I feel like I learned a lot of useful skills, just with the computer just because, I thought I knew everything about the computer when I didn't. I didn't know how to do the Excel, I do now. I didn't know how to do HTML, I do now… And then just I learned a lot of useful skills, like how to make a website. One day, what if I want to make a website? How to make a professional PowerPoint? It ties into a lot of things you do in school, and then probably when you're working, the resume, and the website because what if you're a secretary and you have to work on a website for your bosses? It's just really useful for outside of school and school*
	Gains in collaboration, critical thinking, leadership	*It helped me with advancing my critical thinking because with coding you need a lot of brainstorming, and I still don't. But I used to be even more impatient than I already am, and so I would just stare at a project and I would get mad because I wouldn't know what's wrong with it. So, I would just give up. But now it helped me think, "what can connect well? what will crash? what will fix itself?"*
Engage in project-work that uses CS to create change in the world	Applying CS knowledge/skills to increase awareness of societal issues	*Well, anxiety and stress is like one of those disorders that are basically common to basically every high school student or adult, child. And we wanted to make a mini website about how to prevent or basically help people that are in anxiety and stress situations*

Table 6 (continued)

Finding *Students exercise critical agency when they…*	Examples	Illustrative quotations
Try-on new identities and/or envision "future selves" in CS	Identifying as a coder	*Student states that he thinks of himself as a coder "a little bit" then draws a distinction between his interest in text- vs. block-based coding: "Coding with words isn't really my thing, but block-coding, I like it a lot, so, using things like Scratch, things like that."*
	Course experience sparking an interest	*When you made the thing, you know that you made the music, right? And, if it sounds good, you know that coding is why you did it, and you may become more fond… and it may make you want to get into music or get into coding, because the result that it has from it*
	Prompting consideration of future CS course-taking	*It definitely gave me a better perspective on all this technology stuff with the website and all that. I knew a lot of things about technology before it but the activities kind of helped me deepen my understanding and so that I could move onto computer science class next year*

Table 6 (continued)

Finding *Students exercise critical agency when they…*	Examples	Illustrative quotations
Leverage assets they bring or develop through their CS project work	Serving as an "expert" for their peers	*Me and one other person…, were kind of the g- to's for help. "Cause we had both coded before. We both know everything."*
	Drawing on knowledge, experience, and interests related to CS	*I guess ever since I remember I've been interested in computers. I like doing stuff from computer, making my own stuff. I guess I'm a very creative person*
	Drawing on previous knowledge/ experience with project topics	*Because I see everyone, my friends they're like, "This water's really nasty, like disgusting." It was getting irritating because everybody doesn't want to bring their own water because it's like wasteful, you know, waste of money… And then I was kind of getting so pissed about it, like, "Someone needs to fix this.".. And then I started saying, "Oh, let's do that one. Let's do unhealthy water fountains, so they can see, and so they can know they need to fix it."*

creating materials based on their research was motivated by a desire to effectively reach their audience. One student, investigating the topic of racism, noted that "I had to go really deep into it. I had to really figure a way to get the truth out." Indeed, this student's narrated PowerPoint presentation was one of the more comprehensive examples we reviewed. The presentation included slides detailing the students' research on the history of racism, illustrative cases of racial violence, statistics on racial discrimination, existing approaches to addressing racism, and students' ideas for solving the problem of racism.

Consistent with this student's goal to use their project to "get the truth out," our review of student work revealed that, across both teachers' classes, nearly all presentations, websites, and games created by students focused explicitly on increasing awareness of each group's chosen topic. For example, the homepages of many websites include an explicit call to action wherein students declare their stance or intent to address their chosen problem. The homepage created by a second group that focused on racism states, "This website is about getting rid of racism. Sadly, it's a VERY prevalent thing across the world. People are blinded with ignorance…well, we are going to be the ones telling those ignorant people

Table 7 Unit 1 topics by school

School	Topics (number of presentations)	
Dogwood	Anxiety (3)	Murder (1)
	Confidence issues (1)	Racism (4)
	Depression (2)	Car accidents (2)
	Depression/suicide (1)	Drunk driving (1)
	Mental health (1)	Debt/college debt (3)
	Mental illness (1)	Obesity (2)
	Stress (3)	Food and fitness (1)
	Sleep deprivation (6)	Health issues in the Southeastern US (1)
	Drug abuse/addiction (3)	Injuries in high school sports (1)
	Drugs and peer pressure (1)	Family separation at the border (1)
	Drugs in school (1)	Fixing ubisoft servers (1)
	Bullying (4)	Ocean and marine pollution (1)
	Police brutality (1)	Phone devices distracting students (1)
	School shootings (2)	Boredom (finding things to do) (1)
	Overcoming adversity (1)	
Riverbend	Busses arriving late (10)	Too much homework (7)
	Crowded busses (1)	School lunch problems (3)
	Contaminated drinking	Sleep deprivation (1)
	Laziness (1)	Sleeping in class (1)
	Drugs in schools (1)	Water/lead poisoning in schools (8)
	Drunk driving (1)	Access to alternative education (1)
	Teachers TAKING PHONES (1)	Getting along with siblings (1)
	The school day is too long (1)	

to grow up." Although student groups varied in the degree to which they completed the full arc of CAPACiTY activities, with a sub-set of students not fully developing their games in Unit 4, each group produced multiple artifacts in which they used their CS skills to share their newly developed understandings of a variety of societal issues. Table 7 lists the issues taken up by students at each school.

Agency as Identity Development

Student reflections on the impact of the course highlighted examples of what Holland and colleagues (2001) described as "improvising" or "trying on" different identities. About half the students interviewed indicated that they saw themselves as a coder after completing the course, sometimes offering qualifying statements about the level of their coding expertise. For instance, one student stated, "I wouldn't consider myself a good coder, but I mean, if you can code certain things, you're a coder but you have to get the practice to get proficient at it." Similarly, another student drew a distinction between his interest in text- vs. block-based coding: "Coding with words isn't really my thing, but block-coding, I like it a lot, so using things like Scratch, things like that." In addition to describing instances of CS identity development, students occasionally described taking on other identities related to curriculum activities. For example, in the following student's description of their experience with EarSketch, the student declares, "I was a composer":

> I liked with EarSketch how they had like so many different styles to choose from, and then you can go and find your own sounds and then pull it in. That was fun because a lot of people including myself went in and found completely crazy sounds to play in our final song or final sound. That was just really fun. I felt super creative after doing that. I was like, I was a composer.

A number of students also discussed how collaborative group work–simulated future roles they imagined assuming in industry settings. For example, one student described collaboration as a highlight, stating, "It helped me understand how teamwork would work if I had a group of co-workers with me making the website, and understanding how each role would work."

Interview and focus group data suggest a number of ways in which CAPACiTY may have inspired students to envision future selves in CS, beyond their immediate experiences in the course. Students often discussed how they perceived the world, and their future success, to be increasingly dependent on technology. One student noted that "the world just keeps advancing and you're going to need more and more coding for things in the future." Asked if they would recommend the course to other students, students often stated that they felt it would be particularly useful for students interested in pursuing CS. When describing experiences with coding, in particular, some students described how the experience sparked an interest that they planned to pursue further. For example, one student described how using coding to create music that "sounds good" may lead students to "get into coding" (see Table 6).

Although students did not always express an interest in taking future CS courses, students who did intend to pursue additional CS coursework attributed their interest to their experiences in the course. Asked about whether the course had influenced her future plans, one student stated, “I think it’s impacted me big because I kind of wanna get into things like game design now, because that was interesting to me.” This student went on to share that she is considering taking AP CS and game design “to develop my skills more, so I can try to get a career in that.”

Agency and Student Assets in CAPACiTY

Consistent with Basu and colleagues’ (2009) finding that students strategically drew upon a variety of resources as they exercised agency, we also found that students leveraged the assets they brought to the IDT course. We defined assets broadly to include students’ interests, existing knowledge and skills, and past experiences. Interview data indicate several ways in which students leveraged previous experience with and knowledge of technology, as well as their more general funds of knowledge, as they completed their projects.

Students who reported an interest in technology or CS before beginning the course often described past experience with coding and technology. In some cases, students were exposed to coding and technology concepts as early as elementary school, gaining experience through coursework, summer camps, or informal experiences. Although examples of students describing themselves as “experts” in CS were rare, students with strong CS identity often reported that a pre-existing interest in technology motivated their enrollment in the course:

> I guess ever since I remember I’ve been interested in computers. I like doing stuff with computers, making my own stuff. I guess I’m a very creative person. I like to say. It’s something that really interested me because previous years, I’ve taken computer classes as well.

These students reported that they were able to leverage this experience by applying their knowledge of CS concepts to their projects. Some of these students were able to serve as experts for their peers, citing what they considered more advanced CS knowledge or skills. Other students described how they were encouraged to explore CS because of exposure to family members working or training in the field of CS, contributing to a developing interest in CS. One student who described himself as a “computer guy” described his motivation for taking the course in terms of his family’s tech background: “My dad, he’s a web developer and my mom’s in graphic design. My brother’s also studying computer science in college. My family’s really techy. I thought maybe I should give it a try too and learn coding.”

Many students who did not report a strong interest or background in CS prior to entering the course nonetheless described leveraging assets related to their knowledge and skills of certain technologies, developed through frequent interactions with technology in their daily lives, such as by using video games, cell phones, or computers. In these cases, students’ familiarity with certain technologies served as an asset that helped them connect course content to their interests outside of school, improving their understanding of those technologies.

In addition to CS interests and knowledge, students indicated that they appreciated the opportunity to draw on their life experiences and personal interests when selecting topics for their projects. For example, one student described how she leveraged her personal experiences with her group's project topic, depression, to create a website to share information on coping with mental illness:

> I was in charge for filling the parts for the homepage and the problems section, like describing what depression was and how it was caused, why this mental illness was a problem. It was good to get it all out of my system, because I've dealt with depression before. I've seen people that I'm close to deal with it. It's just something that I want to tell people more about, so they know how to deal with it. Or they know how to deal with it if their child is affected by it, or their partner.

In addition to sharing experiences with particular topics, students spoke more generally about how working on projects with relevance to their lives helped motivate them because, as one student noted, if "it's something you enjoy and know about from your life, then you're probably the most likely to get it done."

Interestingly, just as students drew on funds of knowledge within the course, students also shared examples of applying their newfound CS knowledge beyond the context of the course. One student reported that their new skills in website design would help their family business, stating, "I'll be able to help my dad, since he has a business. Maybe start him a website, too." Another indicated they were able to help their sibling with "website building" noting, "I was able to help my brother out. He's in fourth grade. A little project with that."

Research Question 2: Curriculum Support for Student Agency

With its foundation in CAPs, the curriculum was intended, by design, to foster student agency. However, we did not necessarily know a priori which features of the curriculum would be most important or successful in supporting agency. Analysis of student work products and the perspectives students shared through interviews and focus groups help to illustrate whether and how the curriculum's intended mechanisms for supporting agency actually worked in CS classrooms. Through this analysis, two features of the curriculum emerged as critical for student agency: providing multiple moments of agentic possibility and prioritizing student voice and choice.

Multiple Moments of Agentic Possibility

Students' reflections on the curriculum revealed that a broad range of activities resonated with individual students and that, while certain activities tended to be particularly conducive to agentic work, there was significant variation across students in which aspects or portions of the curriculum figured most prominently in discussions of using CS to create change. Thus, it became apparent that, in order to offer opportunities for as many students as possible to exercise critical CS agency, it was important that the curriculum was iterative, offering multiple moments of agentic possibility.

How students described agency across the four units of the curriculum reflected students' preferences for creating certain types of work products or working with certain digital technologies. Although some students engaged in critical CS agency throughout the course, it was common for students to describe or demonstrate agency either through music technology using EarSketch or game design using App Inventor. As they described their project work, students also noted preferences for certain roles within their groups. For example, in one focus group, a student shared that they liked the Quality Assurance role because they were able to "make sure everything was okay. I went over it, read over it, and got to understand everything and made sure there was no errors or at least minimize the errors."

Notably, although we expected students to exercise critical agency primarily through project work, we found that supplemental course activities also served as important opportunities for students to develop or exercise agency. In the following example, students commented on the authenticity of the course's resume-building activity that required using HTML to build and format their own resumes:

> We made resumes with our HTML, and so by the time we finished with it, I was like "wow, I didn't realize I could put this much on a resume and how to make it look this nice." Because now I have resume, because I am in 10th grade, I'm going to get a summer job. Now I have a resume to use, so this class was very helpful, with getting help for that.

Thus, in this example, the student highlights the resume as a work product that facilitates her agency when it comes to advancing her position in the world, through securing a summer job.

We were also interested in students' responses to the curriculum's video profiles telling the stories of diverse students pursuing CS careers. In these videos, undergraduates from historically underrepresented, marginalized groups reflected on their experiences as CS majors, shared stories of how and why they decided to pursue CS, and discussed their CS career aspirations. When asked about their impressions of the videos, students' reflections were mixed. Some students did not recall the videos as a salient aspect of the course while others indicated that the videos were powerful, prompting them to envision future selves in CS. For example, one student reflected on the videos, stating, "Those were inspiring. They shared their story and they kind of made you think 'Hey, that's me. I can do that.'" Asked to elaborate on what they found interesting about the videos, this student added:

> Well, a lot of them had gone into college without even knowing anything about coding, like they just knew they wanted to do it. And in the end they knew a lot and they were able to succeed in the classes and that was really cool.

This notion that the CS students profiled began with limited knowledge or interest in CS was a recurring theme in students' reflections on the videos. Another student recalled how some of the students portrayed in the videos "weren't even thinking about coding":

> Student: That the stories they came from, they might not have had as much, and then some of them, they weren't even thinking about coding, but then once they got into it they really started to like it a lot, and I guess that was good.
> Interviewer: Yeah, did you learn anything interesting or unexpected from those videos?
> Student: That anybody can code. No matter who you are.

As intimated by this student's declaration that "anybody can code," students indicated that the videos led them to consider new possibilities in CS, often highlighting the ways in which the students profiled applied CS in a variety of fields.

Thus, the curriculum's structure, with an extended project arc that exposes students to numerous approaches to using digital technology to create authentic work products (presentations, websites, music, games), various roles within each of those project experiences, and supplemental activities supporting agency, increased the likelihood that individual students would find openings to exercise agency as they engaged with the course.

Student Voice and Choice

Students in both teachers' classes expressed that being afforded the agency to select their own topics was a highlight of the course and something that differentiated the IDT course from the other courses. One of the clear variations in implementation observed between the two classrooms pertained to teachers' approaches to facilitating problem identification. Whereas Susan led students through a fairly open-ended brainstorming process in which they identified and then narrowed down potential project topics, Patricia chose to bound the problem selection to school-related issues. Consequently, the problems addressed by students in Susan's class were more global than in Patricia's class (see Table 7). There were a few students who agreed with Patricia's approach to problem selection, sharing that they thought selecting problems based on their own school community was more manageable than addressing broader societal issues. However, the majority of students shared the sentiment of one of Patricia's students who stated, "It probably would've been more engaging if the topics had been slightly more open in their scope." Indeed, student descriptions of project work revealed that Susan's students tended to be more invested in using CS to increase awareness of their problems than Patricia's students. Note, for example, how the following student in Susan's class highlights project choice as a defining feature of the course:

> It's different from a normal class because in just a typical school environment, you are actually doing stuff you're forced to do these tasks and stuff like that… I feel like it can help by giving you that freedom of expression in whatever you

> want to do. It doesn't just hold you to one specific area, it opens up your mind or something that you've learned more things about the topics that you actually picked.

As evident in the following student's reflection on their experience with App Inventor, students often highlighted opportunities to "make anything they want," such as music they enjoyed or games they found interesting or fun to play:

> I liked how you could create any game. It was all started from scratch and you could make anything you wanted. It was yours to control. It was like your own personal world. You could create stuff and once you make it anybody can enjoy it if you want them to.

As intimated by this student's assertion that once they make something in the course "anybody can enjoy it," students often commented on the authenticity of their work in the course, describing how they applied CS to create work products that held value in the "real world" rather than merely assignments completed for a grade. For example, one student compares her experience in the IDT course to other courses in terms of opportunities to create authentic work products, stating, "I get to actually put my work in… like I actually did it and I made something out of it. I actually made my own, we made our own game. We didn't just like learn about it and like talk about it. We actually did it."

By examining student products alongside focus group and interview data, we were able to identify instances where student choice in topics translated to a greater degree of completion and higher quality in the websites and games students created. For example, in one focus group with Susan's students, a student shared that she was excited to work on the topic of marine pollution "because I love the ocean and I like animals." Our review of student work products found that this student's website and game (see screenshots in Fig. 2) were among the most sophisticated and complete in either class.

Just as students appreciated opportunities to engage in project work centered on real-world problems of their choosing, they were also sensitive to missed opportunities to address problems that matter to them. The experience of one group in Patricia's class is illustrative. As described in the following focus group excerpt, based on their shared experience, the students in this group focused their project on the water quality in their school:

> Student 1: Initially, in the beginning of the year, the water was iffy. So, we were like, we should do something on this because we noticed…
> Student 2: We all kind of had the same problem. I went to the, not that water fountain, the one from all the way down at the end of the hall is kind of clean. But I went to one that's around the other side, and there was like brown water dripping from it. So I was like, "hmm." And I clicked the button, and it was just like, just disgusting water, just brown and gray and stuff. I was like, "eeew!"

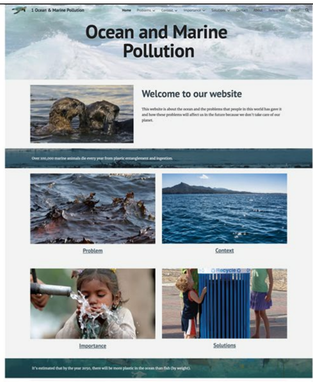
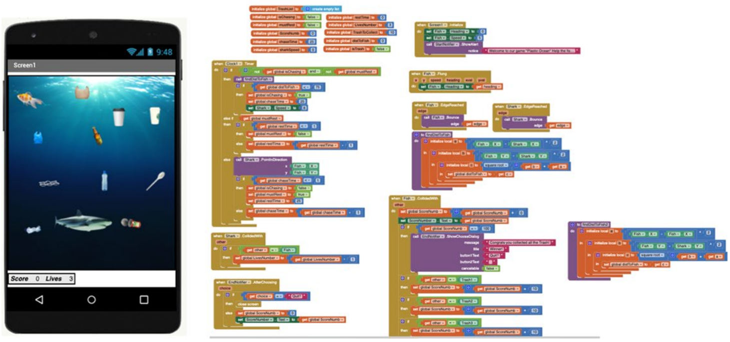
Ocean and Marine Pollution Website	
App Inventor Game and Code	

Fig. 2 Example student products: ocean and marine pollution website and game

> Student 1: So then we all kind of agreed on that and we were like, "yeah, I noticed dirty water." And he was like, "yeah, me too." "Yeah, me too." And then we're just like, "okay." And it was all over.
> Student 3: And that was kind of like a new idea, because everybody else is doing simple stuff, like too much homework, buses being late and all that stuff….This was like new. It wasn't like one of the examples that everyone else would get.

This group's initial enthusiasm for the project contrasts with their disappointment in how the project culminated. One student shared his reaction when he found out that their website was not actually going to be published, stating, "like the websites we made… Didn't even publish them. Like, it was just like, 'why are we making a website when we're not even going to do anything with it?'" Similarly, they shared their disappointment when they realized that they would not be presenting their project to their class or the school's administration, as had been promised:

> Dirty water mattered to us. We wanted to publish that website and make the presentation to spread it throughout the school. And then we find an actual problem that nobody else is doing. We actually want to share with people…. It wasn't one of the five examples that she put on the board and everybody else did. It was like this is an actual problem that we noticed and it just kind of went to waste.

Students' recognition of their effort to identify an "actual problem" rather than a topic suggested by the teacher both underscores problem identification as an opportunity for critical agency and suggests that, as a consequence of the two teachers' different approaches to problem identification, this opportunity was not necessarily available to all students. Although students in Patricia's class clearly took pride in their effort and the quality of their project, they ultimately felt that their work "just kind of went to waste" when promises that they would be able to publish and share their work with the school administration went unfulfilled. Thus, for this group, exercising agency meant not only producing a personally meaningful project but also sharing their work in ways that had the potential to make a difference in their school community.

Discussion

The results of this study illustrate how engaging youth in culturally relevant CS experiences can convey valuable opportunities to exercise critical agency. Consistent with previous research on critical agency in science, mathematics, and engineering education (Basu et al., 2009; Godwin & Potvin, 2017; Turner & Font, 2007), we found that student agency manifested through three aspects of students' experiences with the CAPACiTY curriculum: the application of CS knowledge and skills, exploring or "trying on" CS-related identities, and leveraging assets students brought to or developed through their CS project work. Additionally, our analysis identified two features of the curriculum that were particularly conducive to critical CS agency: a curriculum structure that provides multiple moments of agentic possibility and the inclusion of meaningful opportunities for student voice and choice.

Possibilities for Critical Agency through the Acquisition of CS Knowledge and Skills

The study illustrates agentic possibilities that arise when students are invited to apply and deepen their CS knowledge and skills in ways that matter to them. Consistent with calls to engage students in ways that build sociotechnical literacy (McGowan & Bell, 2020), as students worked through the CAPACiTY curriculum, their learning of CS knowledge and skills was emergent, developing through the process of creating authentic, personally relevant CS work products. In some cases, the curriculum invited students to build on their existing knowledge to do more with familiar technologies, such as creating more sophisticated PowerPoint presentations, thereby supporting agency by elevating the quality of student work products and allowing them to more effectively reach their intended audience. In other cases, students' acquisition of new CS knowledge expanded the creative possibilities for students' projects, as when students applied newly developed programming skills to digitally compose music to enhance their websites. Students' reflections in interviews and focus groups and our review of student work products revealed a certain unevenness in student engagement in agentic work according to students' preferences for certain roles or for working with various digital technologies. Because openings for exercising agency were taken up differentially across students and student groups, iterative project work and offering multiple moments of agentic possibility to appeal to students with diverse interests and identities was a key element of the curriculum's potential to foster critical agency.

Critically, when discussing what they learned through their projects, students highlighted advances in their technical skillsets (e.g., coding, web development, game development) as well as increased proficiency with practices related to the social context of doing CS—leadership, communication, collaboration, and persistence. Although we did not include observations of student groups at work, our review of the work products students produced, as well as students' descriptions of their project work, was reminiscent of the interactive, social nature of critical agency described by Schenkel and Calabrese Barton (2020), and engagement in subject matter communities described by Basu and colleagues (2009). Additionally, many of the learning outcomes students identified as particularly important resonated with the epistemic practices and social contexts of engineering described by Cunningham and Kelly (2017), suggesting the need for future research that looks more closely at the epistemic practices of CS.

Using CS to Create Change

Students clearly indicated that they valued the opportunity to undertake projects that address real-world problems. Whether students took on widespread societal problems like racism or localized issues like school busses running late, students reported that having the opportunity use their CS skills to increase awareness of their chosen topics clearly distinguished the IDT course from their other courses. In the spirit of one student's report that "we didn't just like learn about it and like talk about it. We actually did it," students consistently underscored the value of using their CS knowledge and skills to create authentic, "real" work products. At the same time, as illustrated by the case of the water quality project group, we found that when students' motivation for completing projects stems from a genuine desire to make a real difference in the world, they take that responsibility seriously. Indeed, for these students, publishing their website and presenting the findings of their research with school administrators were far more important outcomes than completing their project for a grade. Thus, student investment in personally meaningful projects comes with an imperative to provide opportunities for students to disseminate their work in the "real world."

Students' affinity for developing authentic work products, along with our finding that student voice and choice were particularly facilitative of critical agency, lends support to the use of PBL as a pedagogical approach to culturally relevant CS and a particularly useful vehicle for supporting critical CS agency. Indeed, many of the features of the curriculum that emerged as influential for agency—voice and choice, projects involving inquiry and iteration, opportunities to showcase work products—are foundational to PBL. When those aspects of project work were sacrificed, students' exercise of the critical agency was curtailed.

Experimenting with Practice-Linked Identities

The sequence of CS activities within the CAPACiTY curriculum enables students to experiment with various CS-related identities (coder, composer, game/app developer) in a relatively low-stakes, low-risk learning environment. In a few cases, students even described how they drew on their course experiences to assume CS-related identities outside of the class, as was the case with the student who planned to use his new web development skills to help his family's business. Importantly, as a foundational CS course, IDT did not require prerequisite CS or STEM courses. As such, students' opportunities to "try-on" practice-linked identities (Nasir & Hand, 2008) were not reserved for students with a deep interest in or prior experience with CS. Indeed, certain activities within the curriculum, such as the assignment for all students to develop a resume listing their CS knowledge and skills and viewing videos profiling diverse undergraduate CS students, sought to gently guide students to envision themselves in CS. We were pleased to find that students' descriptions of "trying on" CS identities occurred fairly broadly, with clear examples among both students who considered themselves coders when they entered the course and those who had never considered assuming a CS identity.

Student Assets and Critical CS Agency

As in Basu and colleagues' study (2009), which found that students strategically drew upon resources when exercising agency in science, many students in our study described how they leveraged assets they brought to their experience with the curriculum. For some students, assets were closely connected with CS, as in the case of a student who brought his coding experience from a summer program to his group's work composing music using EarSketch. A number of students described how their strengths related to creativity helped them exercise agency to create products they were excited to share outside the context of their CS classroom so that, as one student put it, "anyone can enjoy it." Perhaps most resonant with the intent of CAPACiTY, we found that students commonly drew on their unique perspectives and life experiences as they selected, researched, and developed work products addressing problems in their schools and communities. In this way, CAPACiTY created unique opportunities for what Gutierrez (2008) defines as horizontal learning, in which students are invited to bring diverse ways of knowing into the classroom.

Limitations

Although this study lends insight into new possibilities for CS education, it is not without limitations. By collecting data from a significant proportion of students participating in the curriculum, we were able to catch glimpses into a wide range of student experiences. However, our interviews were relatively brief and we were not able to conduct observations or multiple interviews with the same students over the course of CAPACiTY implementation. Students also varied in the degree to which they provided rich responses to questions in interviews and focus groups, with some students providing detailed descriptions of their experiences and others providing much shorter responses or participating minimally in focus group discussions. This limitation was mediated somewhat by the relatively large amount of interview and focus group data collected. However, studies using ethnographic methods or collecting data longitudinally could provide more nuanced accounts of student agency in CS courses.

Our findings are also somewhat limited by differences in implementation in the two school settings where the study took place. Both student interviews and student work products indicate differences in curriculum implementation. For example, we know that the two teachers took different approaches to facilitating problem identification and selection, with one teacher allowing students to identify a broad range of societal problems and the other focusing students' problem identification on localized problems at the school level. While we have highlighted implications of this variation for student agency in this study, we aren't able to provide a detailed picture of the ways in which teachers' adaptations of the curriculum either facilitated or limited agency. Future work that triangulates curriculum implementation data (e.g., classroom observations, teacher enactment logs, teacher interviews) and student data could lend further insight into how the specific pedagogical decisions CS teachers make either facilitate or hinder critical agency.

Conclusion

Our study lends support for culturally authentic approaches to PBL in foundational high school CS courses. Specifically, the study highlights the ways in which students applied and deepened CS knowledge and envisioned CS-related identities as they developed authentic work products designed to raise awareness of problems that matter to them. By exploring these various dimensions of student agency in the context of a high school CS course, the study illustrates how the conceptualization of critical agency applied in other STEM education contexts can also serve as a useful lens for examining student agency in CS.

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Declarations

Conflict of Interest The authors declare no competing interests.

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