Computing for Communities: Designing Culturally Responsive Informal Learning Environments for Broadening Participation in Computing

Diane Codding, Hui Yang, Chrystalla Mouza, & Lori Pollock

Despite increased attention on promoting access to computer science among all students, female and racially minoritized youth continue to be underrepresented in STEM, often lacking opportunities for computer science due to under-resourced schools and a lack of teacher preparation. As a result, K-12 schools are unable to fulfill the goal of expanding access and broadening participation in computing alone. In this paper, we examine how our university-library partnerships can provide access to computer science instruction while attending to issues of social justice through culturally responsive informal learning design. Findings provide insights related to the design, implementation, and outcomes of informal computing clubs for youth from diverse backgrounds.

Introduction

In recent years, there has been increased attention on promoting access to computer science (CS) among all students. Yet, female and racially minoritized[1] youth continue to be underrepresented in STEM, often lacking opportunities for CS due to under-resourced schools and a lack of preparation for CS teachers (Margolis, 2017). CS careers offer economic opportunities, and our society continues to rely heavily on technology, making it increasingly important to broaden participation in CS (Blikstein, 2018). Additionally, increased diversity brings new and important perspectives to CS careers, which help prevent serious design flaws and produce technologies that better serve diverse communities (Vakil, 2018).

K-12 schools, however, are unable to fulfill the goals of expanding access and broadening participation in computing alone. Rather**,** informal institutions such as public libraries, community-based organizations, and after-school programs should play an active role in supporting formal school efforts and providing resources potentially unavailable in K-12 classrooms (Kumasi, 2010; Lee et al., 2018). Importantly, efforts to promote CS in both formal and informal environments should be guided by equity pedagogies—pedagogical approaches that leverage and support students' racial, cultural, and gendered identities to further develop their learning and CS identity development (McGee Banks & Banks, 1995; Madkins et al., 2020; Vakil, 2018). In this paper, we examine the ways in which ongoing university-library partnerships can support efforts to broaden minoritized youth participation in computing through culturally responsive informal learning design that advances student computational thinking (CT)—an approach to problem-solving that draws on fundamental CS concepts.

Informal Learning Design to Promote CT

Although efforts have been made to increase access, CS participants continue to represent a homogeneous group with few females or racially minoritized participants (Master et al., 2016). Research suggests we can address this challenge of inequitable access by promoting local partnerships with both formal and informal learning environments and implementing service-learning programs where carefully mentored undergraduates with a CS background assist local providers using research-based and equitable pedagogical practices (Ericson & McKlin, 2012; Yang et al., 2021). Local partnerships between universities and libraries can serve to promote computational thinking (CT) and expand access to rigorous CS instruction by engaging diverse populations and leveraging students' sociocultural backgrounds (Maloney et al., 2008; Summers & Buchanan, 2018). CT skills are fundamental to participation in computing—they help students learn to address real-world problems like a computer scientist by breaking down complex problems (decomposition), identifying trends (pattern recognition), focusing on relevant details (abstraction), and developing sequential instructions to solve problems (algorithm design). Although scholars argue that CT is an essential analytical skill for 21st century citizens (Wing, 2006), minoritized youth frequently lack opportunities to develop CT skills effectively through the creation of computational artifacts (Repenning et al., 2015).

Libraries are unique learning environments, which have reinvented themselves in response to 21st century needs by offering a variety of low-tech and high-tech activities intended to improve computational skills among youth in their communities (Myers, 2009). In fact, libraries have started to generate interest as designed learning spaces that seek to develop and enact programs that engage youth in computing (Lee et al., 2018). Nevertheless, research documenting the ways in which university-library partnerships can help promote youth CT knowledge and CS identity development is sparse (e.g., Yang et al., 2021). Some prior work on introducing programming in libraries aimed at identifying the types of resources that could be used to foster CT learning (Bilandzic, 2016; Koester, 2014). However, prior studies did not examine how to design effective learning environments that honor the backgrounds and experiences of minoritized youth while addressing design challenges associated with out of school efforts to broaden participation in computing.

A Culturally Responsive Approach

Traditionally, research in CS education has relied upon cognitive orientations to learning at the expense of sociocultural and situated perspectives (Grover & Pea, 2013; Vakil, 2018). Our work takes a culturally responsive approach to designing informal learning environments for the purpose of broadening participation in computing, particularly among females and minoritized youth. Specifically, we seek to offer accessible and culturally responsive CS programming in partnership with local public libraries, where youth can develop their CT knowledge, skills, and identities. Taking a culturally responsive approach is important for engaging minoritized youth in CS by designing a program that leverages their sociocultural identities and promotes a sense of belonging in the field of CS. Our approach draws on theoretical foundations related to the design of learning environments with an emphasis on sociocultural perspectives (Falk & Storksdieck, 2005) and culturally responsive frameworks (CRF) (Gay, 2000; Ladson-Billings, 1995; Paris, 2012; Pollock, 2008; Scott et al., 2013, 2015).

In this work, we utilize four specific strategies aligned with CRF: (1) research-based CS practices for teaching and engaging a diverse population of youth (e.g., pair programming where two programmers work together on a single computer); (2) practices that build on the knowledge and assets of communities (e.g., valuing collaboration over individualism); (3) undergraduate CS students as facilitators and near-peer mentors; and (4) culturally responsive interactions between facilitators and youth underrepresented in CS (e.g., relationship building, positive behavior management, anti-deficit views of minoritized youth and communities, commitment to valuing youth's funds of knowledge) (Codding et al., 2019; Yang et al., 2021).

A key objective of our culturally responsive approach is the design of informal learning environments that help youth develop positive computing identities and foster a sense of belonging within the field of CS. An individual's computing identity is shaped by their experiences with CS (Goodenow, 1993), and constantly reevaluated based on their interactions with others (Goldston & Kyzer, 2009). Computing identities are culturally situated and intersectional (Goode, 2010), because individuals experience CS in classed, gendered, and racialized ways (Livingston & Sefton-Green, 2016; Rodriguez & Lehman, 2017). A sense of belonging is informed by how an individual perceives their acceptance, respect, inclusion, and support (Goodenow, 1993). If students lack a sense of belonging, it negatively impacts their motivation, psychological well-being, and connection to the space (Maestas et al., 2007). If students develop a strong sense of belonging in CS, it can help them to overcome self-doubt and persist in their study of CS (Veilleux et al., 2012). Facilitators can increase belongingness by interacting with students in a culturally responsive and affirming way that acknowledges, values, and incorporates students' cultural backgrounds, identities, and knowledge (Pollock, 2008). Additionally, female and racially minoritized facilitators are uniquely positioned to adjust expectations of who can become a computer scientist (Friend, 2015).

Purpose

In this paper, we examine the ways in which ongoing university-library partnerships attend to issues of design through CRF to support youth participation and CT learning. Specifically, our work is guided by three interrelated objectives. First, we investigate challenges related to the design of informal learning environments for CS learning and present the decisions facilitators made to address those challenges. We focus on design challenges specifically because of the unique flexibility, voluntary attendance, and drop-in nature of youth participation in informal settings, which makes it difficult to design cohesive offerings and anticipate outcomes (Lemke et al., 2015; Martin, 2019). Second, we examine how these decisions reflect the facilitators' positionality and use of CRF to facilitate culturally responsive interactions and create an affirming learning environment. Third, we provide a reflective analysis of how design decisions have influenced the implementation of our informal computing program and shaped youth experiences. Our analysis is shaped by the following research questions:

1. How are facilitators implementing CRF to identify and address challenges while designing informal learning environments that support the development of youth CT skills?
2. How does facilitator positionality inform the process of designing informal computing programs?
3. How do facilitators' design decisions grounded in CRF shape youth computing experiences?

Methods

Context

This work is situated in a larger effort to broaden participation in computing through a three-pronged approach: teacher professional development, a college field-experience course, and sustainable partnerships (Pollock et al., 2015). In this paper, we focus on the latter two strategies. The field-experience course, facilitated by the authors, combines college classes with field-experience in formal or informal settings. The class meets weekly to discuss CS pedagogy (including equitable pedagogy), identify and implement CS teaching resources, write and model CS lessons, and reflect on experiences. In the field, groups of undergraduates meet with educators weekly to plan CS lessons, lead activities, and facilitate after-school programs. Although participants do not intend to pursue teaching careers, they enroll in the course with a desire to share their CS expertise with others and to strengthen their technical communication skills (Mouza et al., 2016; Mouza et al., 2020).

This paper examines two such partnerships between undergraduates and public library staff members. The *Scratch Technology Club* (STC) is facilitated in partnership with Library A and serves a community that is 72% White, 9% Black, 9% Asian, and 7% Latinx. The *Coding Club* (CC) is facilitated in partnership with Library B and serves a community that is 35% White, 38% Black, 6% Asian, and 21% Latinx. While these programs serve different populations of youth, they share a similar mission; they both seek to support youth through CRF as they develop CT skills and a sense of belonging in computing. Table 1 illustrates the specific computing tools and CT concepts selected and taught by the program facilitators at both libraries. As part of the partnerships, the public libraries provided resources and logistical support.

Table 1

Computing Tools and CT Concepts

Category	STC	CC	Concept Description/Example
Technologies	**Makey-Makey**	**Makey-Makey**	**Electronic invention kit that can turn everyday objects (e.g., bananas) into computer keys**
	Finch Robots	Finch Robots	Programmable robot
	Ozobots	Ozobots	Programmable robot that can identify lines, colors, and codes
	Scratch	Scratch	Block-based programming platform for creating interactive stories, games, and animations (scratch.mit.edu)
	Tinkercad		3D modeling program for turning designs into 3D printable models
		PencilCode	Collaborative programming site for drawing art, playing music, and creating games (pencilcode.net)
CT Concepts	Loops	Loops	Scratch programming blocks such as "repeat # times," "forever," and "repeat until" that allow for repeated execution of code
	Variables	Variables	Manipulation & modification of data
	Sensing	Sensing	To detect different factors of project such as color
	Conditionals	Conditionals	If-Then Statements
	Operators		To script math equations using Boolean blocks such as ( ) < ( ).
	Broadcasting		Messages that are used to communicate with multiple sprites

Each program is designed and facilitated by undergraduates with the support of library staff. Any youth interested in participating were permitted to attend, though many had no prior experience with CT. Table 2 provides an overview of the STC and CC programs during the two semesters of this study. During Semester 1, CC held two additional sessions as a pilot program specifically targeting a group of high school youth from nine different charter schools, which all utilized the library as a bus stop. Participants in these pilot sessions were primarily Black and female. In Semester 2, CC was relaunched to target the bus-riding youth after the successful pilot program.

Table 2

University-Library Partnership Programming

Semester	Program	Format				Participants	
		Sessions	Length	Total	Frequency	Ages	Attendance
S1: Fall	STC	10	2 hrs	20 hrs	Saturdays	7-15	5-7 youth
	CC	5	1 hr	5 hrs	1st & 3rd Tuesday	8-15	5-7 youth
		2 (pilot)	1 hr	2 hrs	2nd Tuesday	13-16	6-8 youth
S2: Spring	CC	7	1 hr	7 hrs	Tuesdays	14-18	4-5 youth

Participants

STC and CC were facilitated by undergraduate CS students from the authors' Research University and a State Technical College (*N*=9). Table 3 provides demographic information for facilitators. The Research University students (*n*=7) participated in our field-experience course, which included three 45-minute culturally responsive training sessions led by the lead author. During the first session, facilitators were introduced to culturally responsive pedagogy and learned to adopt affirming attitudes toward youth from culturally diverse backgrounds (Ladson-Billings, 1995). During the second session, facilitators engaged in an activity to take inventory of their own intersectional identities and reflected on the student populations they were working with in the field. Facilitators also received a list of culturally responsive strategies, such as focusing on positive behaviors and expecting their students to do their best while giving them support and tools to do so. During the third session, facilitators discussed the importance of taking a personal interest in each of their students and reflected on their shared interests in order to develop rapport and guide design. This session focused on helping facilitators deepen their sociocultural consciousness to promote equitable and inclusive CS education (Pollock, 2008). The State Technical College students (*n*=2) worked as library interns and were introduced to our culturally responsive approach during a one-hour orientation meeting prior to serving as CC facilitators.

Table 3

Facilitator Demographics

Semester	Facilitator	Program	Gender	Race	Year	University
S1: Fall	**Carrie**	**STC & CC**	**Female**	**White**	**Sophomore**	**Research University**
	Jose	CC	Male	Latinx	Sophomore	Research University
	Kathy	STC	Female	White	Senior	Research University
	Nancy	CC	Female	White	Sophomore	Research University
S2: Spring	Anthony	CC	Male	Black	Sophomore	State Technical College
	Chloe	CC	Female	White	Freshman	Research University
	Logan	CC	Male	White	Freshman	Research University
	Mark	CC	Male	White	Senior	Research University
	Yasmine	CC	Female	Black	Freshman	State Technical College

Youth who attended CC in Spring were invited to participate in a focus group. Out of the 25 youth who attended at least one CC session during Semester 2, nine agreed to participate in our study. Table 4 provides demographic information for participating high school youth (*N*=9).

Table 4

Focus Group Demographics

Race	n	Gender	n	School	n	Grade	n	Attendance	n
Black	**5**	**Female**	**7**	**Charter**	**4**	**9th**	**4**	**1-2 sessions**	**5**
Latinx	3	Male	2	Military	5	10th	4	3-4 sessions	1
White	1					11th	1	5-6 sessions	2
								7 sessions	1

Data Collection

Data were collected from multiple sources each semester. In the Fall, data were collected from three sources: (a) facilitators' weekly reflection journals (*N*=40); (b) facilitators' end-of-program reflections on content and pedagogical decisions (*N*=4); and (c) detailed field observations of all sessions of CC and STC to ensure the reliability of the data set (Hatch, 2002). In the Spring, data were collected from three sources: (a) individual interviews with program facilitators (*N*=5); (b) focus groups with youth participants (*N*=9); and (c) detailed field observations of all sessions of CC.

Weekly Reflection Journals. Facilitators were required to reflect upon their teaching experience at the program every week. In their reflection, they needed to briefly report the implemented lesson components (e.g., learning activities, covered CS concepts) as well as their reflections about their teaching, including what went well in their lessons, what did not go well, as well as questions that they had during their teaching. The length of their weekly journal entries ranged from 200 to 400 words.

End-of-Program Reflection. Facilitators were required to provide a holistic end-of-program reflection as they completed their field teaching experience. The requirements of this reflection included asking the facilitators to provide anecdotes or evidence about how their teaching had changed throughout their 10-week teaching experience, such as comparing their pedagogical approaches at different time points throughout their teaching experience. The average length of the end-of-program reflection was about 700 words.

Facilitator Interviews. Following the final session, facilitators participated in semi-structured, 30-minute interviews, during which they answered approximately nine questions about their experiences facilitating CC (e.g., *What were some of the challenges of facilitating CC at Library B?*), their knowledge and perceptions of youth participants (e.g., *How would you describe the strengths youth brought to CC?*), and their motivation for becoming a facilitator (e.g., *What influenced your decision to become a facilitator?*). Interviews were audio recorded for transcription.

Youth Focus Groups. Youth were invited to participate in one of two focus groups following the final session. Participants were asked seven questions about their experiences with and impression of computing following the program (e.g., *How comfortable are you with Scratch programming? Could you see yourself taking computing classes at school?*). Focus groups were audio recorded for transcription.

Data Analysis

To address the first research question, reflection data were analyzed using a combination of open coding and *a priori* developed during a previous study of 80 weekly journal reflections to identify challenges faced by instructors and decisions to address those challenges (Yang et al., 2019). Two researchers first went over the coding scheme to redefine the categories using several journal reflections (Table 5) and subsequently coded the data from each program based on the updated coding scheme.

Table 5

Reflection Journal Coding Scheme

Category	Sub-Category	Definition
Challenges	**Diverse Learners**	**Learners' diverse background with programming, skills, interests, and culture.**
	Uncertainty of Participants	Unknown participation rates for weekly sessions
	Limited Resources	Limited physical resources (laptops) and human resources (support)
	Learner Engagement	Issues related to learners' content knowledge – returned learners mixed with new learners
Decisions	Addressing Personal Factors	Decisions related to learners' personal characteristics which support a successful learning experience (e.g., prior knowledge, sociocultural background, experience with CS, motivation)
	Addressing Sociocultural Factors	Decisions related to collaboration, use of tools, and culturally responsive relationship development

To address the second and third research questions, interview and focus group data were analyzed with a focus on understanding how facilitator positionality and CRF impacted participant experiences and learning environment design. Observational data were used to triangulate findings. Our analytical approach was inspired by grounded theory (Glaser & Strauss, 1967) and open coding was used to develop a coding scheme from emergent themes (Strauss & Corbin, 1990). Themes fell into two overarching categories: (1) the influential aspects of facilitator positionality, which included their personal experiences with CS education, computing identity, and positionality; and (2) the impact of CRF design decisions, which included curriculum design, building trust, and promoting a sense of belonging within CS and the library.

Results

Identifying and Addressing Design Challenges within CRF

Our first research question examines how facilitators are implementing CRF to identify and address challenges while designing informal learning environments to support the development of youth CT skills. Findings from reflective journal data provide insights into how facilitators implemented CRF in the design and implementation of informal computing programs for youth from diverse backgrounds.

Informal Learning Design Challenges

Facilitators discussed four types of challenges while considering learning environment design. The first challenge focused on designing a learning environment that helped *all* youth, independent of their background, develop CT knowledge and skills. Carrie documented these challenges after her first week at STC: "After teaching one class, I have learned that the greatest challenge with teaching in a library setting will be catering to the needs of all students."

The second challenge focused on varying participation rates among youth, ranging anywhere from zero to ten participants. For instance, the facilitators of both clubs were never sure which youth would be in attendance. Moreover, new youth joined every week with varying degrees of CS background knowledge. Such transitional participation made it difficult to plan activities and prepare equipment to meet the participants' needs.

The third challenge, limited resources, often worked in combination with the second challenge. This resulted in facilitators raising concerns about how to balance and maximize effectiveness: "This week we had the highest number of students with a total of 12, so students had to share laptops and tools which is why we had them work in pairs" (Kathy, STC). Facilitators also faced challenges associated with support from library staff, due to limited knowledge in computing. Although facilitators initially anticipated supporting library staff in the delivery of computing programs, expectations changed after meeting with the staff. Jose (CC), explained: "Ms. B is not equipped to run the program due to IT not being her area of expertise and other responsibilities she has at the library. This meant that [we] have to step into the leadership position and run the program."

The fourth challenge was a culmination of the first three. With continually new and diverse learners, ongoing uncertainty of participation, and limited resources, facilitators found it challenging to engage youth in the learning activities: "When explaining the basics of Scratch, many of the returning students were bored and didn't want to pay attention, while some of the new students struggled" (Carrie, STC).

Addressing Challenges with CRF Grounded Decisions

Throughout the programs, facilitators applied CRF while making decisions, which included both content and pedagogical considerations, based on personal, sociocultural and physical factors.

Personal Factors. As facilitators' knowledge of participants developed, so did their ability to make reflective and engaging decisions addressing personal factors. Facilitators frequently collected participant feedback through observations and conversations, modifying their plans based on youth engagement and feedback from the previous week. CC facilitators learned that their participants enjoyed friendly competition: "We did a Finch maze with the high schoolers, making it complicated with thin lanes and twists and turns. The kids had a lot of fun coding their robots and we timed them individually against their friends. They got really competitive with it and continued to edit their code to make their robots beat previous times" (Nancy, CC). Participants used masking tape to create their own Finch maze on the carpet with passages wide enough to navigate their Finch robot through the maze (see Figure 1).

Considering most youth lacked prior CT knowledge, facilitators sought to make CT concepts engaging and relevant. They provided youth with knowledge and skills to construct personal, meaningful artifacts and helped them establish a linkage between CT concepts and their applications. Carrie (STC) noted, "This is a good lesson plan because it relates algorithms to things they can easily understand, like the steps they take to get ready in the morning. This lesson also uses a fun activity, making paper airplanes, to engage students." Facilitators carefully weaved the tools and CT concepts (Table 2) with participants' interests and real-life applications into a lesson design, such as incorporating the idea of using robotics in serving food at school cafeterias.

Sociocultural Factors. With participants from diverse backgrounds, facilitators promoted a socially interactive and collaborative environment, allowing peers to communicate, share personal meanings, and construct learning together. To accomplish these goals, facilitators utilized collaborative learning. Kathy (STC) explained, "We had each student work with a peer to create their final scratch project. They had to include certain features that we have taught them over the semester … All the students were familiar with performing these tasks but the difference in this project was they had to create a sprite for themselves and their partner. They also had to interact with their partner, ask them what they like to do, and include it into the project."

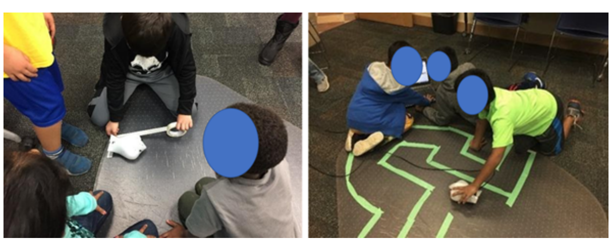
Participants often brought new friends or family to the club. Youth were frequently observed talking, sharing, and helping each other. Facilitators leveraged these sociocultural factors to increase attendance and engagement. Nancy (CC) explained, "I was worried that the high schoolers wouldn't want to come to the program, as I'd been told [by the librarians] that they always said no when asked to come to the coding club, but after [we] convinced one girl to come, about five others followed." In this example, it is clear that facilitators recognized social capital as one of the many assets youths brought to CC.

Additionally, facilitators designed an affirming learning environment that encouraged culturally responsive interactions between facilitators and diverse participants. This can be observed in Jose's (CC) reflections about his communication skills. He stated, "I believe that becoming a better instructor goes beyond having the knowledge in my head and involves a lot of communication skills that make or break my effectiveness as an instructor." In a later reflection, he expanded on this desire for effective and affirming communication: "I am now more aware of the language and tone I use when talking to the kids because of the impact my words have on their takeaway and experience with [the] computer coding club" (Jose, CC).

Physical Factors. Program facilitators frequently rearranged the physical settings to create a more effective learning environment and maximize participation. Lacking space and resources, Kathy and Carrie decided to rearrange the room to better facilitate participants testing their Finch Robot programs. They divided participating youth into two groups and assigned them a carpet and tape to create mazes. Groups then worked to code their Finch Robots to complete the mazes (Figure 1). CC facilitators also addressed physical factors while seeking to expand participation by building Finch Robot mazes in the hallways to attract new participants and increase engagement.

Figure 1

Participating Youth Divided into Two Groups Collaborating on Finch Robots



(Photo 1) A group of three elementary-aged students watch as a fourth student uses masking tape to create a maze on the floor for their Finch Robot.

The Role of Facilitator Positionality in the Design of Informal Computing Environments

Our second research question examines how facilitator positionality informs the process of designing and adapting informal computing programs. Findings revealed that facilitator positionality helped to establish affirming, near-peer relationships with participants and situated facilitators as advocates for expanding and diversifying participation in computing. Facilitators drew from their own experiences with CS, computing identity, and positionality while designing the learning environment and connecting with participants. Anthony (CC) focused on cultivating youth interest in CS, because his own interest had "fizzled out" when he was younger. His goal as a facilitator was to keep youth participating in CC each week and pursuing CS in their formal education. Anthony used his own computing identity to connect with and inspire youth. Similarly, Chloe (CC) chose to become a facilitator in hopes of inspiring youth to become interested in CS at a younger age than she had. Chloe was not exposed to CS at school or through informal programming. Instead, she first discovered coding while watching a movie with her father, which led her to begin exploring it on her own. Like Anthony, Chloe uses her own computing identity to make connections with and motivate youth during CC.

Facilitators also leveraged their positionality to connect with youth over shared identities. Female and racially minoritized facilitators were aware of the ongoing homogeneity in CS, a field that continues to be dominated by white males. Female facilitators like Chloe used their gender identity to disrupt the stereotype of CS as a male-oriented field: "I feel like if you can get younger children, especially girls, to get into those fields it will shift the field to a different perspective in the near future" (Chloe, CC). Black facilitators also leveraged their racial identity to connect with youth and highlight the importance of increasing racial diversity in CS. Having seen the limitations of CS within racially minoritized communities, Yasmine (CC) emphasizes the importance of increasing diversity in CS as a way to ensure equitable access to the benefits of technological advancements. Yasmine explains that diversifying CS would address inequities, such as soap dispensers that fail to recognize hands with darker skin: "If they had someone with darker skin helping with the design, then the soap would've come out."

The Role of CRF Design Decisions in Shaping Youth Experiences

Our third research question examines how design decisions, grounded in CRF, shaped participating youth experiences in the informal computing environment. Findings indicated that by implementing CRF, facilitators were able to design engaging activities for diverse populations of youth, provide a space where youth could experience a sense of belonging, and build trust with participating youth and librarians.

Designing Engaging Activities. Facilitators used research-driven and equity-based practices to promote engagement in computing activities (Madkins et al., 2020). These practices included hands-on collaborative activities, project-based learning, tiered activities, community projects driven by student interest, CS Unplugged (i.e., activities that teach computing concepts in kinesthetic ways away from the computer), and paired programming. Facilitators used hands-on collaborative activities to help youth build their confidence in computing: “I think it’s a way for kids to be introduced to something they might not be introduced to, that is going to have a large impact on the future” (Anthony, CC). After participating in CC, youth self-reported that they felt highly confident (80% to 90%) in their computing abilities and they could see themselves continuing to study CS in their formal education. Facilitators also reported seeing an increase in youth confidence over the course of the semester-long program. During the focus groups, youth also identified hands-on and creative learning opportunities as one of their favorite features of CC, such as remixing a Mario themed Scratch game to be controlled using bananas and a Makey-Makey. Creativity and tiered activities helped facilitators adapt to new groups of participants each week. Chloe found that such strategies helped facilitators to “spread [CS] out to the community more, since it is more of a communal building rather than a school.” The youth also emphasized the fact that CC was unlike school due to the hands-on activities, welcoming atmosphere, and positive relationships with the near-peer facilitators.

Building Trust. Facilitators leveraged culturally responsive interactions with youth (Pollock, 2008) to increase student engagement and promote a sense of belonging. Prior to joining CC, many of the bus-riding youth did not feel welcome within the library. The librarians warned us about their tense history with these youth during our first planning, describing them as unruly “monkeys” who needed to be “pulled down from the trees.” This casual use of a racist stereotype reflects a lack of cultural understanding among library staff and highlights the need for a justice-centered approach to CS programming that challenges their deficit view of the bus-riding youth (Vakil, 2018). Participating in CC helped youth experience a sense of belonging within the library and rebuild their relationship with the librarians. Anthony sought to make CC a place for participating youth to have fun, pushing back on the idea that libraries are reserved for quiet reading and homework. Facilitators sought to change the atmosphere and expectations of the space by personally inviting youth to participate, acknowledging the youth’s desire to socialize and relax after school by frequently joking and laughing together. Further, facilitators frequently helped youth with their homework, talked to them about college, and bonded over shared interests. Through these activities participating youth began to trust the facilitators and turn to them as near-peer mentors. Additionally, the facilitators gained the trust of librarians, who began to change their perception of the bus-riding youth.

Designing a Space to Belong. The facilitators succeeded in designing CC as a space where youth could experience a sense of belonging and community within the library. During focus groups, youth reported that their favorite part of attending CC was spending time with the undergraduate facilitators. Facilitators who shared underrepresented gender and racial identities with participating youth were able to leverage their near-peer relationships to promote engagement in CS activities. Chloe (CC) developed a strong bond with the female participants: “We had good conversations every time they came. And I think they were just excited to see me come back every week.” White male facilitators reported having a harder time connecting with the youth, who were primarily Black and female. However, this did not prevent facilitators from getting to know the youth. Logan reported successfully getting to know the youth by helping them “get their own perspective” and interests into their projects. One student who was initially unenthusiastic about coding, spent several weeks developing a Harry Potter themed game that showcased her knowledge of quidditch and wizardry: “I loved making my game. … I loved my Harry Potter game” (focus group). Facilitators intentionally designed CC to be a welcoming space, where youth could engage with computing at their own pace and bond with facilitators over shared interests.

Discussion and Implications

Our university-library partnerships attend to issues of educational equity through culturally responsive informal learning design. Specifically, we address issues of access by attending to personal, sociocultural, and physical factors in our computing programs. The challenges we uncovered in this study are not necessarily unique to our programming. For instance, the issue of uncertainty in participation has been well-documented in the literature (Martin, 2019) and can be addressed through the design of activities with multiple entry points as well as activities that allow students to go deeper in their interests (Ito et al., 2013). Yet findings indicate the need to help facilitators *anticipate* these challenges in advance and create plans for addressing them. For instance, future professional development opportunities for university facilitators should more explicitly address challenges associated with the (a) drop-in nature of youth participation; (b) diverse backgrounds of participants in informal settings both in terms of sociocultural identities, content knowledge, and interests; and (c) availability of computing resources in each setting. Such opportunities should also connect facilitators to existing resources, including curricular materials as well as pedagogical strategies that help differentiate CS tasks based on youth background knowledge and personal interests.

To increase access, we apply CRF to help youth develop a sense of belonging in both the informal learning environment and in the field of computing. These frameworks include leveraging facilitator identity to promote positive, near-peer relationships with female and racially minoritized youth. Therefore, intentionally recruiting racially minoritized and female facilitators is an important part of promoting diversity in computing. Those most at risk of being left out are youth who do not regularly see themselves represented in the field, specifically female and racially minoritized youth (Valenzuela, 2017). Therefore, facilitators from underrepresented backgrounds can, and should, serve as role models for youth as they envision their future selves (Penuel et al., 2019).

Informal learning environments are uniquely situated to prioritize learner-centered and interest-driven computing opportunities (Penuel et al., 2019; Yang et al., 2021). While STC and CC facilitators prepared lesson plans and thoughtfully selected activities to engage their specific participants, some of the most engaging moments happened outside of the curriculum, such as a carefully designed Harry Potter-themed game. Applying CRF to informal environment design requires constructing CS curricula that are culturally relevant and rigorous (Madkins et al., 2020), yet flexible enough to allow youth to bring in their own interests and identities into their computing projects (Yang et al., 2021). Therefore, facilitators should be encouraged to design curriculum and pedagogical approaches that reserve space for student interest, choice, and creativity in order to allow their learning to reflect more of their own identity and interests within the context of CS.

While CC facilitators were able to engage bus-riding youth in CS programming despite early warnings from the librarians, our programming did not do enough to permanently alter the racially-charged relationship between the librarians and the Black bus-riding youth. In future cycles of our university-library partnerships, we hope to expand our culturally responsive training to include additional space for engaging librarians in the important work of addressing biases, stereotypes, and deficit views in order to reshape the library as a positive learning environment and promote a sense of belonging among youth, especially Black youth, within the library. In Vakil's (2018) vision for a justice-centered approach to equity in CS education, he envisions "homelike learning environments" in which "learning is organized in ways that seamlessly honor the depths of student experience and the range of identities they carry with them into the learning and design process" (p. 44). In order to make this vision a reality, our university-library partnerships need to expand our culturally responsive approach to address systemic racism and cultivate an affirming learning environment.

Limitations

There are two limitations associated with this work. First data were collected only from a small number of facilitators and participating youth. Therefore, results may not reflect the views and experiences of all participants. Second, this work did not examine youth outcomes in terms of CS content knowledge or identity development. Rather, the focus was on the manner in which equity pedagogies were taken up by facilitators and the ways they shaped youth experiences. We agree with Madkins et al. (2020), however, that future research needs to consider the effectiveness of equity pedagogies in CS learning, interest, and engagement using both proximal and distal measures.

Conclusion

In this paper, we provide evidence on how program facilitators, with support from university faculty and librarians, regulated and adapted the design of the library clubs. Findings of this study provided insights related to the design, implementation, and outcomes of informal computing programs for youth from diverse backgrounds. This work is significant for creating a foundation for culturally responsive approaches to designing informal learning environments for broadening participation in computing. This foundation will lay the groundwork for creating community partnerships that promote equitable access and making computing relevant to youth from underrepresented communities. Further, this work helps establish the importance of community partnerships for designing culturally responsive and equity-focused computing programs. Looking forward, we hope to determine how the cultural context of each library impacts the culturally responsive decisions necessary to increase student engagement and to design an affirming learning environment.

Footnote

[1] The use of the term 'minoritized' considers that majority or minority status of certain groups does not always match numerical representation. It reflects a concern with capturing actions and processes through which certain racial/ethnic groups are subordinated or denied equitable opportunities (Shields et al., 2005).

References

Bilandzic, M. (2016). Connected learning in the library as a product of hacking, making, social diversity and messiness. *Interactive Learning Environments*, *24*(1), 158-177. https://edtechbooks.org/-Ihry

Blikstein, P. (2018). Pre-College computer science education: A survey of the field. Mountain View, CA: Google LLC. Retrieved from https://edtechbooks.org/-BtF

Codding, D., Mouza, C., Rolón-Dow, R., and Pollock, L. (2019). Positionality and belonging: Analyzing an informally situated and culturally responsive computer science program. *Proceedings of 8th Annual Conference on Maker Education* (FabLearn '19), Mar. 9-Mar. 10, 2019, New York City, NY, USA. https://edtechbooks.org/-dMAN

Ericson, B., & McKlin, T. (2012). Effective and sustainable computing summer camps. *SIGCSE '12: Proceedings of the 43rd ACM technical symposium on Computer Science Education*, 290-294. https://edtechbooks.org/-vXsN

Falk, J., & Storksdieck, M. (2005). Using the Contextual Model of Learning to understand visitor learning from a science center exhibition. *Science Education, 89*(5), 744-778. https://edtechbooks.org/-coqK

Friend, M. (2015). Middle school girls' envisioned future in computing. *Computer Science Education*, *25*(2), 152-173. https://edtechbooks.org/-PQLj

Gay, G. (2000). *Culturally responsive teaching: Theory, research, and practice.* Teachers College Press.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Aldine Publishing.

Goldston, M. J. D., & Kyzer, P. (2009). Teaching evolution: Narratives with a view from three southern biology teachers in the USA. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *46*(7), 762-790. https://edtechbooks.org/-nbF

Goode, J. (2010). The digital identity divide: How technology knowledge impacts college students. *New media & society*, *12*(3), 497-513. https://edtechbooks.org/-vEZn

Goodenow, C. (1993). The psychological sense of school membership among adolescents: Scale development and educational correlates. *Psychology in the Schools, 30*(1), 79-90. https://edtechbooks.org/-whSS

Grover, S., & Pea, R. (2013). Computational thinking in K–12: A review of the state of the field. *Educational researcher*, *42*(1), 38-43. https://edtechbooks.org/-kEmt

Hatch, J. A. (2002). *Doing qualitative research in education settings*. SUNY University Press.

Ito, M., Gutierrez, K.D., Livingstone, S., Penuel, W.R., Rhodes, J.E., Salen, K., Schor, J., Sefton-Green, J., & Watkins, S.C. (2013). *Connected learning: An agenda for research and design, research, and practice*. Digital Media and Learning Research Hub. Retrieved from https://edtechbooks.org/-LyAz

Koester, A. (2014). Get STEAM rolling!: Demystifying STEAM and finding the right fit for your library. *Children & Libraries*, *12*(3), 22. https://edtechbooks.org/-rjhb

Kumasi, K. (2010). Cultural inquiry: A framework for engaging youth of color in the library. *The Journal of Research on Libraries and Young Adults.* 2010 Symposium Paper presentations, *1*(1). Retrieved from https://edtechbooks.org/-LTK

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal*, *32*(3), 465–491. https://edtechbooks.org/-EEKBo

Lee, V.R., Recker, M., & Phillips, A.L. (2018). Conjecture mapping the library: Iterative refinements toward supporting maker learning activities in small community spaces. *Proceedings of the 13th International Conference of the Learning Sciences*, June 23-27, London, U.K. Retrieved from https://edtechbooks.org/-biwM

Lemke, J., Lecusay, R., Cole, M., & Michalchik, V. (2015). *Documenting and assessing learning in informal and media-rich environments.* MIT Press.

Livingstone, S., & Sefton-Green, J. (2016). *The class: Living and learning in the digital age.* NYU Press.

Madkins, T. C., Howard, N. R., & Freed, N. (2020). Engaging equity pedagogies in computer science learning environments. *Journal of Computer Science Integration*, *3*(2), 1-27. https://edtechbooks.org/-USsT

Master, A., Cheryan, S., & Meltzoff, A. N. (2016). Computing whether she belongs: Stereotypes undermine girls' interest and sense of belonging in computer science. *Journal of Educational Psychology, 108*(3), 424–437. https://edtechbooks.org/-JmzP

Maestas, R., Vaquera, G. S., & Zehr, L. M. (2007). Factors impacting sense of belonging at a Hispanic-serving institution. *Journal of Hispanic Higher Education, 6*(3), 237-256. https://edtechbooks.org/-xkP

Maloney, J., Kafai, Y., Resnick, M., & Rusk, N. (2008). Programming by choice: urban youth learning programming with scratch. In *39th SIGCSE technical symposium on computer science education* (pp.

367-371). https://edtechbooks.org/-LfbE

Margolis, J. (2017). *Stuck in the shallow end: Education, race, and computing*. MIT Press.

Martin, C. (2019). Designing for STEM in libraries serving underserved communities. In V.R. Lee and A.L. Phillips (Eds), *Reconceptualizing libraries: Perspectives from the Information and Learning Sciences* (pp. 123-139). Taylor & Francis.

McGee Banks, C. A., & Banks, J. A. (1995). Equity pedagogy: An essential component of multicultural education. *Theory into practice*, *34*(3), 152-158. https://edtechbooks.org/-BKCu

Mouza, C., Marzocchi, A., Pan, Y., & Pollock, L. (2016). Development, implementation and outcomes of an equitable computer science after-school program: Findings from middle school students. *Journal of Research on Technology in Education, 48*(2), 84-104. https://edtechbooks.org/-wkkE

Mouza, C., Pan, Y., Yang, H., & Pollock, L. (2020). A multiyear investigation of student computational thinking, practices, and perspectives in an after-school computing program. *Journal of Educational Computing Research, 58*(5), 1029-1056. https://edtechbooks.org/-YaT

Myers, B. (2009). Imagine, invent, program, share: A library-hosted computer club promotes 21st century skills. *Computers in Libraries*, *29*(3), 6. Retrieved from link.gale.com/apps/doc/A195419446/EAIM?u=udel_main&sid=bookmark-EAIM&xid=25a81136

Paris, D. (2012). Culturally sustaining pedagogy: A needed change in stance, terminology, and practice. *Educational Researcher, 41*(3), 93–97. https://edtechbooks.org/-KBx

Penuel, W.R., Chang-Order, J., & Michalchik, V. (2019). Using research-practice partnerships to support interest-related learning in libraries. In V.R. Lee and A.L. Phillips (Eds), *Reconceptualizing libraries: Perspectives from the Information and Learning sciences* (pp. 239-256). Taylor & Francis.

Pollock, M. (2008). From shallow to deep: Toward a thorough cultural analysis of school achievement patterns. *Anthropology & Education Quarterly, 39*(4), 369-380. https://edtechbooks.org/-LIXh

Pollock, L., Mouza, C., Atlas, J., & Harvey, T. (2015). Field experience in teaching computer science: Course organization and reflections. *Proceedings of Special Interest Group in Computer Science Education*, March 4-7, Kansas City, MO. https://edtechbooks.org/-uRRX

Repenning, A., Webb, D.C., Koh, K.H., Nickerson, H., Miller, S.B., Brand, C., Horses, I.H., Basawapatna, A., Gluck, F., Grover, R., Gutierrez, K., & Repenning, N. (2015). Scalable game design: A strategy to bring systemic computer science education to schools through game design and simulation creation. *ACM Transactions on Computing Education, 15*(2), 1-31. https://edtechbooks.org/-TkLf

Rodriguez, S. L., & Lehman, K. (2017). Developing the next generation of diverse computer scientists: The need for enhanced, intersectional computing identity theory. *Computer Science Education*, *27*(3-4), 229-247. https://edtechbooks.org/-JrfM

Scott, K. A., & White, M. (2013). COMPUGIRLS' Standpoint: Culturally responsive computing and its effects on girls of color. *Urban Education*, *48*, 457-681. https://edtechbooks.org/-fPgwe

Scott, K. A., Sheridan, K. M., & Clark, K. (2015). Culturally responsive computing: A theory revisited. *Learning Media and Technology*, *40*, 412-436. https://edtechbooks.org/-wzKJ

Shields, C. M., Bishop, R., & Mazawi, A. E. (2005). *Pathologizing practices: The impact of deficit thinking on education*. P. Lang.

Strauss, A., & Corbin, J. M. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Sage Publications, Inc.

Summers, S., & Buchanan, S. (2018). Public libraries as cultural hubs in disadvantaged communities: Developing and fostering cultural competencies and connections. *The Library Quarterly, 88*(3), 286-302. https://doi.org/10.1086/697707

Vakil, S. (2018). Ethics, identity, and political vision: Toward a justice-centered approach to equity in computer science education. *Harvard Educational Review*, *88*(1), 26-52. https://edtechbooks.org/-Zmd

Valenzuela, J. (2017). Focus on equity to ensure that all students are "computer science materials". Retrieved from https://edtechbooks.org/-LsmY

Veilleux, N., Bates, R., Jones, D., Allendoerfer, C., & Crawford, J. (2012). The role of belonging in engagement, retention and persistence in computer science. In *Proceedings of the 43rd ACM technical symposium on Computer Science Education* (pp. 707-707). ACM. https://edtechbooks.org/-kod

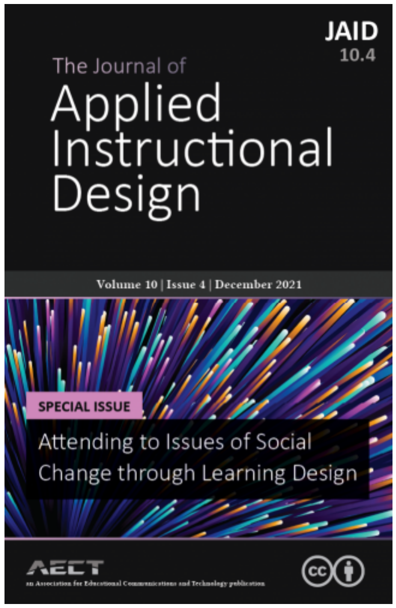
Wing, J.M. (2006). Computational thinking. *Communications of the ACM, 49*(3), 33-35. https://edtechbooks.org/-jB

Yang, H., Codding, D., Mouza, C., & Pollock, L. (2021). Broadening participation in computing: Promoting affective and cognitive learning in informal spaces. *Tech Trends, 65*(2), 196-212. https://edtechbooks.org/-ubcm

Yang, H., Mouza, C., & Pollock, L. (2019). Establishing equitable computing programs in informal spaces: Program design, implementation and outcomes. *Proceedings of International Conference on Computational Thinking Education 2019*, Hong Kong, China. Retrieved from https://edtechbooks.org/-xMgZ

Acknowledgement

Research reported in this article was supported by National Science Foundation under award numbers: 1649224 and 1639649.



Codding, D., Yang, H., Mouza, C., & Pollock, L. (2021). Computing for Communities: Designing Culturally Responsive Informal Learning Environments for Broadening Participation in Computing. *The Journal of Applied Instructional Design, 10*(4). https://edtechbooks.org/jaid_10_4/computing_for_commun