Understanding Instructors' Cultivation of Connectedness in K-12 Online Synchronous Culturally Responsive STEM and Computing Education

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Culturally responsive STEM and computing initiatives aim to engage and embolden a diverse range of learners, center their identity and experiences in curriculum, and connect learners to each other and their communities. With an abrupt pivot to online learning at the beginning of 2020, more educational experiences have taken place virtually. We ran a virtual synchronous culturally responsive computing camp and saw that establishing the right environment online to support a good sense of connectedness was challenging. To investigate this further, we interviewed eight K-12 instructors of culturally responsive STEM and computing programs. Three themes emerged on defining and cultivating connectedness in learning experiences, the role of equity in supporting community online, and affordances of being online specific to culturally responsive perspectives. We support our thematic findings with vignettes from the camp data. In this study, we address K-12 culturally responsive STEM and computing instructors' beliefs, experiences, and approaches regarding cultivating connectedness online. This work fills a gap in understanding instructor perspectives on building in-program and broader community connections online from a culturally responsive STEM and computing lens.

CCS Concepts: • **Human-centered computing** → **Empirical studies in collaborative and social computing**; **Web-based interaction**; • **Applied computing** → **E-learning**.

Additional Key Words and Phrases: online community, online learning, culturally responsive teaching, K-12, computer science education, connectedness

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1 INTRODUCTION

There remains a major lack of diversity in STEM and computing, with disproportionately fewer women, people of color, and women of color in professional positions [42, 51, 52]. Of the total U.S.

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STEM workforce, Black women represented 5.6% in 1995 and by 2015 had only increased to 5.7%. In 2015, women comprised only 35% of the tech workforce, while Black and Latinx women represented 7% and 5%, respectively [7]. Primary and secondary education is a core time for underrepresented learners to become introduced to STEM and computing in a way that impacts their perspectives on their opportunities to make long term contributions to the field [31].

Our work adopts the framework of culturally responsive teaching and computing pedagogies [35, 58, 59]. To address inequities in education, culturally responsive STEM and computing initiatives aim to engage and embolden a diverse range of youth learners, center their identities and experiences in the curriculum, as well as connect learners to each other, outside home communities, and professional networks [32, 58, 59]. One critical underpinning for this work is facilitating connectedness, "a peer culture in which the participants feel linked to each other and their communities" [59]. Connectedness is composed of a sense of *internal* connectedness (learner connections within program) and *external* connectedness (connections to self and society outside program). Culturally responsive pedagogy emphasizes establishing the right environment to support both aspects. Distinct in this framework from other definitions of community is an emphasis on both technology and social justice, as we will detail in related work.

Typically, culturally responsive computing (CRC) programs have been run in person. However, the COVID-19 pandemic has caused a major change in how such synchronous educational experiences are delivered, necessitating a shift to online or hybrid models of delivery. While the initial pivot from in-person to remote learning was abrupt, it likely also marks a permanent change in how we view learning environments, and a broader variety of hybrid and synchronous online modes of educational options will carry into the future [33]. This presents particular challenges for CRC pedagogy. Connectedness is a crucial component of CRC, but establishing a sense of community in online learning is a documented challenge in recent prior literature from the CSCW community [12, 38], let alone community in service of advocacy and social change. We observed barriers and opportunities for community firsthand when we ran a fully virtual synchronous culturally responsive computing camp for middle school girls over three weekends in October 2020. Desiring to further investigate, we then interviewed eight instructors of culturally responsive K-12 STEM and computing programs. In this paper, we explore the viability of supporting connectedness in these types of educational experiences, as well as the unique challenges, new opportunities, and effective strategies that instructors experienced and deployed online.

In our interviews, we specifically focused on culturally responsive STEM and computing programs facilitated by instructors trained in culturally responsive practices to understand how they cultivate connectedness. Three themes emerged from our interviews on how instructors understood, experienced, and supported connectedness in online synchronous culturally responsive STEM and computing K-12 programs. We illustrate these themes with vignettes describing moments from the multi-day online synchronous CRC camp we ran. Interview findings and data from the camp study fill a gap in understanding instructor perspectives and approaches to building learner and broader community connectedness online from a culturally responsive teaching lens.

2 BACKGROUND AND RELATED WORK

2.1 Connectedness in Culturally Responsive Pedagogy

Ladson-Billings [35] defines culturally relevant pedagogy as teaching practices that foster academic success, cultural competence, and critical consciousness, emerging from the imperative to (re) story the academic needs of African American students. As knowledge increased about culturally relevant (also known as responsive) practices on African American and Hispanic student engagement [10, 40], CRT's application spread to the field of STEM education [37]. Our work falls within the

frame of culturally responsive computing (CRC), a "technology education that draws inspiration from the body of work on culturally responsive teaching" [58] to navigate the development of underrepresented learners into techno-social change agents [59]. The implementation processes of CRC are framed by three specific tenets – Asset Building, Reflection, and Connectedness (ARC). This pedagogy focuses on underrepresented learners' development through asset building (integration of technological and content knowledge), reflection (challenging one another to self-examine topics, behaviors, and identities along various divides), and connectedness (knowledge application grounded in culturally responsive methods with peers and broader communities). In this paper, we specifically focus on the core component of *connectedness*.

Similar to CSCW research, connectedness in CRC includes shared objectives and mutual bonds of a community. Differing and adding to the CSCW literature, connectedness is further built on a foundation of advocating for social justice, addressing power, and centering diverse learners.

Connectedness as part of the CRC guiding tenets explicate that students practice coalition building, advocacy, and empathy in a technology-based course. Because technology is not a neutral actor in the world, connectedness promotes student reflection and critical thinking. For example, in an environment for teaching computer science concepts, teachers may also facilitate student discussions on how technology has been wielded as a power tool to maintain majoritarian stereotypical views of disenfranchised groups. As such, facilitators implement connectedness using a problem-posing model for technology instruction. They define the purpose of technology education as a medium for social change and an identifier of inequity. In both formal and informal learning environments, technology facilitators/teachers tend to employ connectedness that include these five characteristics: (1) encourage student voice [6], (2) normalize cultural differences (e.g., acknowledging and celebrating individual differences) [39], (3) critique socio-cultural factors in technology education and workforce [51], (4) position the learner as producers of knowledge [26], and (5) equips the learner to disrupt technological inequities (e.g., racism, sexism, classism) [59].

These five aspects of connectedness reinforce expectations of relationship building that fosters one's personal responsibility to other learners and one's external communities [59]. Connectedness can thus be internal, directed at forming learner-learner bonds. CRC instructors aim to co-create classroom norms with students that value diversity, equity, and inclusion. The anticipated learner outcomes are reflected in examples, such as peer mentoring [68], sharing of lived experiences, and being a critical friend [16]. Connectedness is also therefore external, involving evidence of concern beyond the self to the participants' own communities. We next expand on the definitions of internal and external connectedness.

2.2 Internal Connectedness

Connectedness includes learners' bonds to one another within the culturally responsive computing and STEM environment. It relies on the building of internal community, which can be described as, "a feeling that members have of belonging, a feeling that members matter to one another, and a shared faith that members' needs will be met through their commitment to be together" [43]. While we focus on Scott and White's definition of *connectedness* [59], there is a significant body of related CSCW research on building *community* in learning that can take place virtually, yielding frameworks such as Moore's interaction taxonomy [44], communities of inquiry (CoI) [24, 25], communities of practice [67], and Rovai's concepts of community in distance learning [54].

Prior literature shows a number of academic and personal benefits to having a good sense of community in a learning environment, which include less attrition and greater student persistence [54, 56, 63], higher rates of learner satisfaction [27], as well as more participation and learning gains [55]. However, whether chosen out of necessity or for certain conveniences, learners who are in online learning environments face multiple challenges to experiencing a sense of community,

especially related to social presence and teaching presence, such as lack of feeling connected to the instructor and establishing peer rapport [46] or feeling isolated often, since there exist few social cues to build on in comparison to in-person learning [54, 56].

A commonality therefore between most work on community in online learning which relates to internal connectedness is an emphasis on social presence within the environment: the ability to virtually project oneself [23] and be aware of others[64], as well as on teaching presence, which is the instructors' design and facilitation of learning experiences to promote a good sense of connection among community members [1, 54]. In this paper, we examine how within the online CRC context, learner-learner and learner-instructor interactions foster a sense of connectedness and how this might differ from non-CRC contexts that are less concerned with learner empowerment or non-online contexts.

2.3 External Connectedness

Connectedness from the perspective of self and society incorporates the learner's specific external community connections, extending beyond traditional learning spaces such as classrooms. Our distinction within the CRC framework of internal and external community is similar to how the community of practice literature differentiates between the internal community of school-based educational experiences and an external community that students may connect with when engaging in actual practice beyond structured school activities [67]. However, the CRC idea of external community involves both an exploration of the home communities with which a learner identifies and how the learner can act to effect meaningful change within those contexts. External community in education is not defined by dominant norms that establish the guidelines for knowledge sharing and learning [20]. Instead, the external community expands science content knowledge to the people and places not governed by policies implemented in schools. Pedagogical understandings of external communities contextualize learning that is relevant and connected the learner.

One area where researchers have examined external community is through science education initiatives that focus on social change outcomes for student engagement [47]. Citizen science projects, for example, supplement science instruction with real-life experiences to expose and deepen scientific literacy for students [8, 29, 30, 45, 53]. Unlike classroom-based science education, citizen science projects occur in various places and have been found to provide opportunities for students to interact with community members from different cultural backgrounds [45, 53, 60]. Localized citizen science project origins appeal to students' interests, because content derives from their community. Mueller and Tippins [45] and Zoellick et al. [69] include evidence about curricula outcomes' claim to raise environmental consciousness, increase civic responsibility, scientific literacy, social interaction between schools and professional scientist, advance scientific performance, and provide an added voice through international minority perspectives to the field of science. However, the scope of this approach to democratize science is vulnerable to limited participation by racial and ethnic groups [8], because of factors such as economics, family engagement, blocked access to natural settings, limited science knowledge, fear, and time constraints [49].

In this work, we explore how external connectedness in CRC manifests in an online context.

2.4 Promoting Connectedness

Prior work has mostly explored promoting connectedness in communities of minoritized individuals that may not be in an online context *or* in online contexts without focus on minoritized individuals. In prior work on promoting online community, Thomas's case study [62] presented how children learned and built community together through role play in a synchronous virtual world and asynchronous forum, showing that through online discussion and experience-taking, they

could learn communication skills. Sanders and Lowkey-Vega [57] described how high school social studies teachers moved their classrooms to be synchronous and online, finding that they facilitated engagement and learner-learner discourse by using interactive tools (e.g., Kahoot, Quizlet, polling) and exciting educational videos followed by small group discussions. Drysdale [21] further articulates how assigning mentors or "shepherds" to smaller groups of learners could greatly enhance a virtual program's sense of community. More research is needed to understand the approaches instructors take in a culturally responsive context.

CSCW researchers have additionally created novel technologies to encourage positive social interactions online. One way technological interventions do is by creating new *opportunities* for such positive interactions. For example, systems have been built to automatically identify opportunities for connection [41] or prompt people to offer social support to their peers [28]. In addition to creating new opportunities for social interaction, technological interventions have been built to *improve* the interactions themselves. For example, in virtual spaces, technological interventions have facilitated joint awareness through shared eye gaze [34] or emotion management via chatbots [4]. However, many such existing technology supports or interventions were not designed to center learners with a specific focus on equity, in alignment with the aims of CRC. It is unclear if these may be appropriate for these contexts, and more exploratory work is needed.

While few papers discuss intervention strategies specifically for minoritized groups, there are some notable exceptions. For example, while not online, [13] outlines strategies for creating an inclusive environment within nursing education for underrepresented minorities. Taking a psychological safety perspective, their suggestions range from asking students' directly about their preferences and backgrounds, ensuring that students are exposed to learning environments and materials that represent the experiences of diverse populations, and pointing students to additional resources as necessary.

While technology for virtual learning could support equity, minoritized learners may also face more challenges in online learning environments [22]. The five characteristics defining the work for facilitator/teacher implementation of CRC curriculum could therefore improve this support. For instance, while CRC implementation depends on inclusive learning environments for critical conversations, individual and group reflections, and equal power sharing, online platforms limit styles of teacher-student engagement [50]. The work space online, for example, with the four corners of the zoom window, restricts participation to the standardized audio and video control settings. Even with features like the whiteboard, breakout rooms, or video effects, engagement is still regulated by dominant norms. Teacher adjustments for online CRC implementation requires that one re-imagine teacher-student and student- student methods of relationship-building. Therefore, to effectively support suitable interventions, we can draw on the beliefs and experiences of culturally responsive instructors.

CRC programs aim to uphold the 5 core tenets of the framework in any setting. With the transition to virtual learning, it is essential to understand how programs have facilitated this shift. Little research has explicitly explored instructors' understanding of and actions to facilitate connectedness online in culturally responsive computing and STEM programs. We strive to address the following RQs. In an online CRC environment, what are instructors':

- RQ1: *Experiences* of how connectedness did or did not manifest?
- RQ2: *Beliefs* about how connectedness should manifest virtually?
- RQ3: *Approaches* to supporting the cultivation of connectedness?

We believe that addressing these questions will contribute novel insights into culturally responsive STEM and computing perceptions, practices, and gaps when these programs move online. We later discuss technology recommendations to support these gaps and better facilitate practices.

3 METHODS

In this section, we cover information about the online synchronous culturally responsive computing camp we ran, detail interview recruitment and analysis, and include descriptions of culturally responsive STEM and computing programs. We first ran our own computing camp, finding that there were barriers to cultivating connectedness. This prompted us to conduct semi-structured interviews with instructors of other programs offering similar online synchronous experiences in order to understand their perspectives and approaches to supporting connectedness.

3.1 Online Culturally Responsive Computing Camp

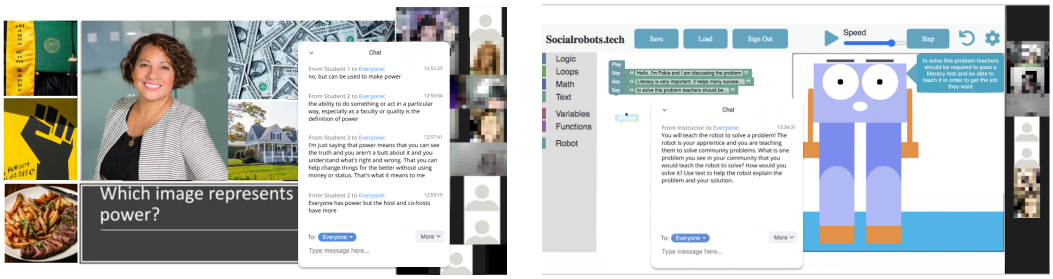

Fig. 1. Two de-identified, recreated snapshots of the CRC camp are shown. On the left is a group-wide activity on power and identity. On the right is a coding activity in a breakout room.

Our informal CRC camp study took place over the span of three consecutive weekends in October 2020 and were 2-3 hours in duration. The camp was held on Zoom (http://zoom.us), and all sessions were recorded. Ten middle school girls, aged 12-14 years old, participated in the virtual synchronous camp. One identified as American Indian, one identified as Asian and White, two identified as Hispanic/Latina, four identified as White, and one preferred not to answer. The camp was run by three instructors and contained a mix of introductory activities on robotics, computer science, and identity and power, e.g., learners reflected on whether certain images represented power and what factors make up their identity. Learners connected these ideas to computer science through tasks to program a virtual robot, e.g., in one activity, learners wrote code to make the robot discuss problems they see in their community and how they would solve them (Fig. 1). Activities took place in a mix of a large group (all learners) and small groups (breakout rooms). Small groups had five learners each (mix of having cameras on and off), one main instructor with their camera on, and another observing researcher with their camera off.

3.2 Instructor Interviews

We first researched culturally responsive STEM and computing programs that held educational opportunities virtually to ensure alignment with culturally responsive goals and practices, taking into account mission statements and program offerings. We reached out via email to organizations for K-12 learners with mission statements and programs that were particularly aligned with the tenets of culturally responsive teaching to invite instructors to participate in the interview study. Due to the high stress and activity levels during the COVID-19 pandemic, we had most success in recruiting from programs with which we had previously been in contact for recruiting for our own program. We were able to conduct seven semi-structured interviews with instructors from three different programs (names anonymized): GirlTech (3), YouthComp (2), and ScienceGirls (2). Instructors from GirlTech and YouthComp had formal understandings of culturally responsive

Table 1. Program details. Programs had a range of ages with mostly girls as the intended learners.

Program	Informal	Age Range	Learner Demographics
GirlTech	Yes	Secondary (high) school	Girls
ScienceGirls	Yes	K-12	Girls
YouthComp	No	Secondary (high) school	Mixed gender
CRC Camp	Yes	Middle school	Girls

Table 2. Instructor demographics. Instructors represented a variety of backgrounds and programs.

ID	Program	Yrs. Teaching	Other Teaching Description	Self-Described Racial Identity
I1	GirlTech	16-20	Elementary school	Black
I2	GirlTech	11-15	Secondary computer science	Asian Pacific Islander
I3	GirlTech	6-10	Elementary & preschool	Japanese
I4	YouthComp	16-20	Secondary computer science	White
I5	YouthComp	6-10	Secondary English	White
I6	ScienceGirls	1-5	None	White
I7	ScienceGirls	11-15	None	White
I8	CRC Camp	21-25	Secondary life sciences & math	African American

computing through professional development opportunities offered through these programs, while the instructors from ScienceGirls had knowledge specifically from practice. We additionally interviewed the second author (I8) of this paper who facilitated the CRC camp we ran for a total of eight interviews. Including an author as a participant has a tradition in education research through research-actor and [65] interacting educator-researcher [19] frameworks.

GirlTech is an informal CRC camp for girl-identified learners in high school, which took place over 9 weeks. Sessions last 2 hours each and primarily took place over Gather.town (https://gather.town/), a web-conferencing platform with a virtual world in which each users have avatars. Curriculum content focuses on cybersecurity and information technology, with the goal being to introduce and prepare participants for futures in tech. YouthComp is a formal CRC high school course (gender inclusive) that is for one academic year in duration. The 120-hour curriculum was moved to be held online over Zoom and includes four quarters focused on technology and social issues, with the goals of positively impacting underrepresented students' attitudes toward and self-efficacy in computing, plans for STEM coursework, and computational thinking skills. ScienceGirls is an organization that offers informal culturally responsive STEM and computing programs for girl-identified participants in K-12. Different camp offerings include robotics, physics, computing, and engineering. Online multi-hour sessions held over Zoom range from one-day workshops to spanning multiple weeks. All programs had the overarching goal of emboldening learners as techno-social change agents to position them to be problem solvers in communities beyond the program.

We asked about instructors' perspectives on connectedness in the programs they facilitated. Interview questions specifically covered what a good sense of community looked like to them online, challenges and obstacles for cultivating connectedness, and approaches used to support connectedness in online culturally responsive STEM and computing programs. Instructors interviewed were female, and five had other teaching backgrounds beyond instructing the camps and were also K-12 teachers. Interviews ranged from 45 minutes to 70 minutes in duration and were conducted virtually over Zoom. Instructors were compensated for their time with a $25 gift card.

3.3 Data Analysis

We conducted thematic analysis of the instructor interview data using an inductive open coding process [15]. The first and third author discussed literature definitions of connectedness in culturally responsive pedagogy [35, 59] to ensure they had similar understanding and then independently reviewed and characterized initial codes from the interview data. Because the definition of connectedness from CRC has both internal and external aspects, this showed in the initial set of codes. They then discussed and combined initial codes supported by data from multiple instructors into themes using an affinity diagramming approach [5]. Then the first author iterated the thematic analysis to further collapse themes and checked in regularly with the other researcher. If there were disagreements in the themes, the authors would discuss, review the data, and confirm or iterate the theme until reaching agreement. Next, member checking (i.e., confirming interview findings with a member of the group being studied) [2] of the resulting main themes was performed with the second author, who ran our online culturally responsive computing camp. Lastly, all other authors came together to discuss and finalize the three themes we present below. To further support and supplement the themes, two researchers reviewed video data of the online synchronous camp sessions and developed vignettes that were illustrative of the themes that emerged from the instructor interviews.

4 FINDINGS

Here we describe the three main themes of our findings across programs and instructors, emphasizing elements that are specific to our instructor population and context while noting some findings which are in line with prior work on non-culturally responsive teachers' challenges to facilitating educational experiences and supporting community. Supplemental vignettes support an understanding of how the thematic findings occur in practice. Throughout the findings, we reflect on how connectedness is displayed, through the lens of the five components described in related work: (1) encourage student voice, (2) normalize cultural differences (e.g., valuing uniqueness), (3) critique socio-cultural factors in technology and STEM education and workforce, (4) position the learner as producers of knowledge, (5) equips the learner to disrupt technological inequities (e.g., racism, sexism, classism).

4.1 Cultivation of a connected learning environment as a journey

4.1.1 Internal community best when learner-led. Instructors characterized a good sense of internal community as being socially learner-led, meaning that learners initiated and carried on social interactions with one another. Accordingly, instructors described their roles as being supportive cheerleaders in the background and not wanting to be perceived as overpowering or authoritarian by the learners. *"As soon as they are kind of leading the way, and I'm just there to click the mouse, they're doing amazing,"* (I6, ScienceGirls). The importance of learners being heard (via voice chat or typed) was particularly emphasized, in line with characteristic #1 in Connectedness.

Furthermore, instructors saw self-disclosure as a sign of and contributing to learners' comfort in being vulnerable with peers and developing friendships, a finding also in prior work [3, 18, 66]. In particular, this often took place through learner-learner side conversations (either on or off topic). Aided by visuals and common space in a virtual world, I2 (GirlTech) described what side conversations look like between learners with good rapport in Gather.town, *"I can see their [avatar's speech] bubbles, like going back and forth... There's constant talking."* Instructors were encouraging of and intentionally made space for side conversations, even if it removed learners' attention from the main curriculum.

In order to support these learner-led interactions, instructors went so far as to reduce their own social presence by watching from a distance or turning off their cameras in order to give learners more space to connect. *"I don't bother them… Like I'll come in, and I'm going to come in with my camera off, so they don't see me like staring at them, like judging them. And I'll tell them, you know, if you need my help, you can ask me, and I'll unmute myself and talk, but I just want to see what you guys are doing. I'm not coming in to tell you what to do. I feel like that gives them a little bit more space, and that helps them build more community,"* (I1, GirlTech). Leader-led environments are an essential prerequisite for positioning the learners as producers of knowledge, as opposed to consumers (characteristic #4). Practice leading helps to prepare learners to disrupt existing systems (characteristic #5).

4.1.2 Heavy facilitation of tone, norms, and peer connections. While learner-led interactions were preferable, instructors reported challenges in cultivating a good sense of internal learner-led community. Instructors spoke to how it was much harder to meet people online for the first time and establish connections and friendships in a virtual environment due to lack of social cues, shared physical space, including physical touch and connection, and inability to engage in some familiar social or cultural norms virtually. I8, the second author, described how *"some communities are very expressive and [physically] touchy, so maybe it hinders how people engage in community without that kind of contact."* In the CRC camp we ran, we explicitly encouraged learners to connect with one another in a number of activities, but we were not as successful in facilitating learners' initiating social interactions with one another, as shown in the vignette:

> *V1. (Coding Task Breakout Room): Instructors encouraged the learners to engage in conversation with each other as they programmed their virtual robot and to discuss any questions they had about code with their peers first before asking the instructor. One learner asked a coding question. This was followed by silence, despite some learners being further along in the task. The instructor stepped in after no response. Instead of talking to peers, some learners asked questions or privately chatted to the instructors in direct messages.*

Instructors therefore emphasized the importance of starting the experience by setting a program's tone, framing a transformative purpose, and modeling community-building behavior to support a good sense of internal community among learners online. For instance, across programs, instructors described wanting their program to have a non-competitive and collaborative tone. This involved cultivating an environment safe for learners to make mistakes and engage in risky conversations in order to connect with peers over ideas, opinions, identity, and culture. I7 (ScienceGirls) described wanting to make camps into *"a space where there's trust and the willingness to open up and say the wrong thing or do the wrong thing… a safe space to fail forward."* In particular, it was further emphasized that setting norms and a tone that was celebrative of risk-taking and learning from mistakes was especially important for emboldening underrepresented learners in computing and STEM. *"BIPOC women are scared to fail... It seems like in a White male dominated world. You are judged based on your failure versus your learning from failure. And then you're also being judged as the representative of your community, especially in these realms that are entirely White male dominated. So giving students… the opportunity to fail in safe spaces helps them lean on each other. And that is really important, I think, especially because cybersecurity is such a competitive world,"* (I2, GirlTech). Instructors emphasized normalizing non-dominant culture in technology (characteristic #2).

Approaches to modeling internal-community-building behavior online included acknowledging when learners spoke, sometimes reading students' chat responses out loud, and practicing self-disclosure about their own identities first, increasing their social presence [17, 61], before asking it of learners. These are common practices for in-person programs, but instructors felt that online, they had to be more intentional and put more energy into modeling these behaviors to establish

positive social norms. As a result, some instructors felt more worn out by facilitating their programs online compared to in-person. *"Why I get so exhausted on zoom is because... I act like a game show host mixed with a kids YouTuber,"* (I6, ScienceGirls). Although sometimes particularly effortful online, instructors overall aimed to model behavior and create opportunities for student participation and opinions (characteristic #1).

4.1.3 Creating opportunities for peer connections and collaboration. In order to help transition away from initial heavy instructor facilitation towards their eventual learner-led goal, two instructors mentioned how they explicitly invited the learners to be a part of defining and setting their own community expectations (e.g., Would their mics be muted when not speaking? What would courage and respect look like?).

Instructors also initiated conversations that would lead to learners disclosing information about themselves, such as round-robin icebreaker questions. Doing so early in the program allowed learners to later find common points of interest amongst themselves.The instructor had to step in more heavily at times to find connections between learners, e.g., by having individual conversations to understand a learner's interests and then connecting them to a peer. *"I help facilitate those connections… They're more willing to [talk] to me [when] they're not totally empowered to go to the whole group… So I will find two people or three people who have those similar interests, and then I'll group them up in the next activity we do together,"* (I6, ScienceGirls).

After instructors got to know their learners, alongside pairing learners with similar interests, they constructed heterogeneous groups such that more outgoing learners (i.e., those with more salient social presence) could specifically engage with shier learners. *"You have those proactive girls that bring out the shine with someone who's very shy… I pair them up with girls who like turning the camera off, you know, because hopefully, maybe they'll say, 'Hey, can you turn your camera on?',"* (I3, GirlTech). They noted general success with this pairing method. Instructors sometimes also assigned roles in groups to aid collaboration. Instructors who already used similar methods in person found them particularly important to employ online due to additional online barriers to learners getting to know and interact with peers, while the other instructors specifically adopted new techniques when they shifted to facilitating virtual programs. Connectedness is evidenced through the instructors' continued valuing of the student voice (characteristic #1). In fact, instructors in our own camp used the strategy of role delegation to enhance connectedness. We did observe that this strategy was successful in eliciting smoother learner-led collaboration in our own camp data, as evidenced by the following vignette:

> *V2. (Robot Identity Breakout Room): In an activity where learners were instructed to collaboratively discuss and decide on aspects of a fictitious social companion robot's identity (e.g., name, gender, likes and dislikes, etc.), one learner was designated by the instructor to share their screen and type out the group's ideas on a virtual whiteboard. This learner subsequently chose to read aloud the robot identity prompts for peers and help pace the group through the list of the identity aspects for the duration of the activity.*

Instructors commented on how this sense of internal community does not happen instantly and has a trajectory. I6 (ScienceGirls) described how the dynamics change within a one-week-long camp, *"[At first], they want so badly to talk to us because we're a new adult in their life, but at the end of the week when they have gotten accustomed to seeing the same girls or the same friends,… [I am] no longer the 'cool' adult… they care more about talking to each other than they care about talking to me."* Instructors hoped that the connections and relationships built would carry beyond the program itself. They noted how good community between learners manifested in them initiating sharing contact info with one another, such as social media handles, emails, and phone numbers, or parents' info (depending on age), in order to be able to contact each other outside of the program.

Supporting learners in networking with one another in the context of a CRC educational experience can help equip them to disrupt technological inequities together (e.g. racism, sexism, classism) (characteristic #5).

Further, instructors created opportunities for learners to collaborate on projects that required an engagement with each other and their external communities. In GirlTech, instructors spoke to a final project where the girls were grouped together and created a public service announcement (PSA) video for their communities on an important science or technology topic of their choosing. Through curriculum development, instructors can facilitate connectedness in the projects they layout. The PSA project that the instructors created allowed learners to bond with one another, as they practiced critiquing sociocultural norms (characteristic #3), producing knowledge and content for external communities (characteristic #4), as well as potentially disrupt an oppressive system with their projects via spreading ideas and actionables (characteristic #5).

4.2 Complexities to achieving equity

4.2.1 Access to supplies and technology. Instructors viewed equity as core to building internal community and inequity as a barrier. Instructors, specifically of the ScienceGirls camps where a number of tactile project activities are offered, missed the ability to have everyone in a common environment with access to the shared supplies. In an in-person environment, everyone has access to the same materials, but online, instructors noted how it was important not to make assumptions about learners' resources. I4 commented that a lack of equity *"illustrates the haves and the have nots. If somebody is left out... it can build resentment… [They] are conscious of what they're missing out [on], and it's stressful for them."* ScienceGirls tried to create an even footing for certain activities by sending out packages with supplies for tactile STEM projects to all participants in advance.

Differing computing devices were also a source of inequity. Some learners had access to more elaborate computer setups, while others may have had access only to tablets or phones. Instructors noted the importance of making activities accessible to a number of learners, since some *"don't have enough real estate on [their] computers to see faces and also code… don't have two monitors… It's just this idea that there were a lot of assumptions that went into play about what abilities students were able to utilize,"* (I8, second author). By reflecting on their own assumptions that initially went into creating online experiences that sometimes did not achieve goals of equitable experiences, the instructors themselves reflected deeply on socio-cultural factors in technology pertaining to learners accessing their programs, although they did not share these reflections with learners (characteristic #3). Despite testing our programming platform that we developed on multiple devices, being fully inclusive to learners who used different devices to participate in the camp we ran was a challenge:

> *V3. (Coding Task Breakout Room): One learner attended the camp on a tablet device. During robot coding activities, the tablet's smaller screen did not display the programming interface in entirety, and the button to run code was not visible. When the learner wrote code, they could not execute their program to make their virtual robot carry out actions.*

Although instructors faced barriers to creating fully equitable experiences in terms of materials and resources, there was considerable thought to create an environment and model a space where there was less resource and technological inequity (characteristic #5). Instructors suggested that activities be designed with consideration to different levels of access to technology, such as chat-based activities. Additionally, differences in experience with using and communicating via computers (e.g., typing, reading) was an obstacle for some learners. *"Communication is a barrier, especially with girls who don't know how to use the chat or don't know how to type. The older girls are definitely a lot more involved with the chat."* (I6, ScienceGirls).

4.2.2 Virtual educational experiences were more accessible due to lower geographic barriers. Some learners were able to more easily join the culturally responsive STEM and computing experiences due to lowered geographical barriers. Instructors commented on how more learners were joining their programs from further away, and this led to a more diverse and wider-reaching sense of internal community. *"We have built a community across the state versus just in our own home communities. And that's important… I think other students need to see that there are like-minded girls… especially if they feel isolated in their own home community, right? 'I'm the only girl that's interested in cybersecurity.' Well, not when you look at the state—you can see a lot of different girls there, and that's important"* (I2, GirlTech). With a more diverse learner population, since some learners who had been previously excluded from these programs due to distance, lack of transportation, or cost, instructors saw that this helped with understanding different cultural differences and backgrounds (characteristic #2).

4.2.3 Philosophies vs. preferences for camera use. Instructors had conflicting views on learners' use of cameras. Instructors generally preferred cameras to be on for common reasons documented in prior work relating to more social information and cues [12]. They often viewed cameras being off as a barrier to getting to know who their learners were. However, all instructors also found that to provide an equitable environment, they could not require cameras to be on for a number of reasons related to learners' privacy, learner boundaries and not being ready to share their spaces (e.g., revealing of vulnerable information like socioeconomic status), other background commotion, and effects on attention. I5 (YouthComp) described requiring cameras to be on as *"not something that was realistic, and it also wasn't something that was helpful in building that kind of sense of community. It was a little more like awkward pressure to feel like the camera was on… students are uncomfortable showing what's going on in their home."* Given that learners have different backgrounds and boundaries, instructors aimed to normalize these differences by allowing for flexibility with camera usage (characteristic #2), even if it was not their preference for learners to have their cameras off. They aimed to design programs that accommodated a range of different types of engagement with technology.

An approach that addressed the camera off or on tension was in GirlTech's use of Gather.town, which helps to establish learner representations (via virtual customizable avatars, even if cameras are off) and provides a common virtual world and some visual feedback for instructors. I2 (GirlTech) described: *"When you turn off your camera, that might be a lack of engagement, but because the avatars are moving, I know that they are still with me."* In other programs that primarily used conferencing software without a virtual space, it became clear that activities had to be flexible for users who did not have cameras on, and some activities that were translated almost directly from in-person to online were less effective. The following vignette illustrates our attempt to facilitate previously successful in-person activities to an online environment, but they did not encourage the same kind of participation or social engagement that we had hoped for.

> *V4. (Group-wide Icebreaker): Learners were asked to introduce themselves with their name, a fun fact, and a physical action. Other learners and the instructors repeated their name and action. Those with their cameras and microphones off used the chat to introduce themselves. There were sometimes periods of silence, as the group waited for the typed introductions. The instructors read out the descriptions in third person and made up actions for them. Learners with their cameras off could not be seen repeating others' actions.*

Although not all activities were effective for learners who preferred only to type, some instructors noted how the option to type instead of talk on camera was better for some to participate and share their opinions (characteristic #1). *"Chat options with girls who usually don't say a lot, even in person,*

they just kinda keep to themselves,... maybe behind a keyboard, they feel a little bit more empowered to jump into the conversation." (I6, ScienceGirls).

4.3 The home environment's unique support of external community

Our last theme is strongly supported by instructors' distinct emphasis on the home environment across interviews. Although some learners were concerned about their backgrounds and privacy, instructors found that for those who had their cameras on, the ability to see personal artifacts in the learners' backgrounds was a benefit to encourage information disclosure and help peers connect with one another. This gave the unique ability for learners to talk about important objects in their home environment, ultimately sparking conversation about their identities and values. This type of disclosure and interaction around artifacts may be harder to achieve in-person, since learners are not immediately in their home environment, and the interaction may be less authentic. *"When we introduce ourselves, I always like showing an object, so that they connect based off these objects that they've been sharing"* (I3, GirlTech). This helped teachers in understanding their students outside of the controlled space of a classroom—in online learning, learners may be more affected by influences in their home.

In the same vein, there was unique potential for parents and other family members to have a presence in the program. Family members who reside in the same home may show up in learners' backgrounds or interact with the learners and subsequently the other program participants. While a busy background may be viewed as negative in some cases (e.g., if too distracting for other learners or the learner is not wanting others to see their family members), this also allows an opportunity for learners to introduce close people in their lives if they so choose. The home environment allowed the ability to center other pieces of identity and culture, acknowledging and celebrating learners' unique differences (characteristic #2). By centering sometimes overlooked facets of identity and creating opportunities to make projects from these facets, learners are emboldened to produce new knowledge from their perspective (characteristic #4).

> *V5. (Group-wide Activity Transitions): One learner received tech support help from a parent multiple times throughout the camp. As the parent made appearances via the learner's camera, short on- and off-topic conversations took place between the instructors and the parent on a few occasions as they aided the learner in setting up their computer and logging into the coding platform.*

A tension emerges between leveraging the background and philosophies on camera use. If a learner does not have their camera on at any point or rarely, instructors and peers may not get to connect with them as well as with learners who have their cameras on. There is a need to structure activities to accommodate learners with their cameras off, so other modalities, e.g., just typing can be equally effective.

Relating to lowered geographic barriers mentioned in the theme above, holding online programs also offered a valuable affordance of having guest speakers, professional networking opportunities from further away, and live tours. For example, in ScienceGirls and GirlTech, learners were able to engage in live virtual tours with universities and network with STEM professionals. Although taking a virtual tour is possible even when learners themselves are gathered in person for educational experiences, this option may have become more salient to instructors as the shift to online learning caused many professionals to"live" online themselves. While we did not hear any evidence that engagements with professionals continued beyond the initial visit, continued experiences like these could present a starting point for CRC coalition building with newly forged external networks.

5 DISCUSSION

In this work, we interviewed eight instructors and report on our own multi-day camp to build an understanding of instructor beliefs, experiences, and approaches to building connectedness within online K-12 culturally responsive curricula. We found that instructors were used to facilitating culturally responsive experiences in-person which felt more natural given their focus on community, and found the online format to introduce a number of challenges. In line with past work, instructors described how internal community is a trajectory [14], but they found that they needed to be more intentional in online learning about creating opportunities for connections. Instructors characterized their intended approach as a learner-centered one, but extended other uses of the term that focus primarily on content [9] to include how learners formed social bonds and engaged in non-content related interactions as ways to encourage student voice and advocacy. However, because of the increased challenge in forming connections online, instructors were often heavily involved early on in the camps to scaffold and model community-building behaviors. This involvement was in contrast with their stated preference for positioning the learners as the knowledge producers, and led to heightened "performances" that made instructors feel fatigued within the initial program delivery.

In the cases where instructor modeling behaviors were not sufficient to induce preferred interactions, instructors found mechanisms for more outgoing peers to do the modeling themselves. Peers were able to be more direct in their requests, such as asking their partners to turn their cameras on. In this way, peers themselves led the normalization of home environment and cultural differences. As camps progressed, this enabled the instructors to reduce their own social presence to prioritize the learner-learner connections being made. Instructors viewed these strengthened connections as a prime instigator of learners' subsequent exchange of contact information and stated intention to continue interacting outside the bounds of the programs. Such formation of long-term coalitions is one of the main objectives of CRC [59].

Online learning also provided new opportunities for external connectedness as a focus. Echoed by vignettes from our camp, new opportunities were found in centering learners' communities and identities outside of the program. For instance, connecting from their home environments enabled a more facile expression of self-disclosure. Learners were able to share about everyday items that held value for them, even introduce family members or pets, in ways that revealed hidden facets of their identity and further normalized cultural differences. As self-disclosure can often be at the surface level [3], this window into learners' lives and home environment let them disclose more deeply, while helping to shape how instructors themselves viewed and addressed their learners' identities. This critical aspect of culturally responsive pedagogy is uniquely enabled by the online setting [59].

Finally, a main tension that our work surfaced was of connection modality, which arose in all themes. Instructors preferred that learners had their cameras on, since they could get visual feedback on learners' engagement (in line with prior work [12]). Additionally, as noted above, cameras were a prime mechanism for providing unique opportunities for external community to come into focus, given the novel ability to gain entrance to learners' home environments. While these features served external connectedness goals impossible to achieve for in-person camps, not all learners were comfortable or able to have a camera on. Instructors thus described a deep conflict felt with goals of equity, noting the importance within the online environment of designing activities that were inclusive for different modalities of engagement, particularly given inequities in access to technology. While core tenets of CRC include the critique by learners of socio-cultural factors in technology education and the equipping of learners to disrupt technological inequities, no instructors described the very fact of this tension or their own camps' inequities as a potential

starting point for such discussions. They may have viewed this as too sensitive or close to the students' own situations to be appropriate for synchronous conversation; and yet, this is a space potentially ripe for exploration.

To mitigate inequities related to participation in different modalities, instructors did describe several approaches to establish common ground, a main pillar of community-building [48]. The technologically-supported approach used by instructors of the GirlTech program - holding the camp in a virtual world - resulted in instructors gaining additional signals of learner engagement (e.g., avatars moving around), even without camera usage, allowing learners with their cameras off to have heightened social presence. ScienceGirls followed a non-technological approach, ensuring that all learners had the same resources via mailing supplies.

Together, these findings lead to understanding the experiences, beliefs, and approaches to supporting the cultivation of connectedness online. Instructors viewed connectedness as learner-led but were challenged with supporting this in an online environment. We saw that instructors experienced barriers to connecting learners and achieving equity, as well as benefits related to celebrating diversity and external connectedness. Instructors were creative, using a number of approaches to overcome barriers to cultivating connectedness, such as employing a virtual world or playing a heavier part in connecting learners to one another. We believe that some of the main challenges instructors faced in cultivating connectedness may be addressed with technological interventions, such as allowing instructors to have more variation in social presence.

5.1 Design Opportunities

Based on our findings, we explored a set of design opportunities for the development of future technologies that could support instructors of culturally responsive STEM and computing experiences. Specifically, we focus on three main themes; supporting learner differences and non-dominant, external connections (within learners' home environment and after the session is over), and supporting co-creation and customization in ways that position girls as technology producers.

With a need to support learner differences and non-dominant norms, virtual worlds, like the Gather.town example used by the GirlTech instructors, are worth further exploration with an opportunity to build on existing and add new features. We saw that virtual worlds offered instructors and learners a shared context, social cues (e.g., speech bubbles), as well as some ability for instructors to change their social presence as needed (e.g., fade in and out of a learners' interaction by walking closer and further from the learners' avatars). In particular, the instructors communicated a unique need to be able to dynamically adjust their own social presence to encourage student voice and position the learners as knowledge producers. The ability to *decrease* social presence is especially interesting, since focusing on *increasing* social presence is usually a focus of online collaborative settings. Developing new types of virtual worlds that provide a full dynamic range of no or minimal to full social presence could enable instructors' goals more effectively.

As another example of a technological adaptation that could further support diverse learners, chat bubbles as a minimal form of social presence were also helpful for instructors to understand what students were doing from afar. Adding more avatar emotes could contribute to instructors' awareness of if and how learners are engaging in the program and with one another. Additionally, in child-friendly virtual worlds, learners may be able to present a stronger sense of identity and expression (in line with characteristic #2) in their social presence with greater ability to customize their avatars, perhaps even allowing them to create artifacts in the virtual worlds to represent objects, clothes, or other customizations.

Second, to better support external connections within the learner's environment and others in the educational program, a new design opportunity relates to the tension that instructors felt with utilizing video streams to learn more about the participants versus allowing them to have their

cameras off. Developing systems that provide a greater ability to support selective environment sharing, such that the learner has more control over what to share in their immediate home environment, could help strike a balance between gaining the benefits of the home's unique support of the external connectedness and honoring learners' boundaries around what they are comfortable with sharing. This could manifest by learners having the ability to show just a section of their background, to spotlight a certain object or being able to easily take a picture of something in their environment with a phone and broadcast it online.

The third design opportunity is using technology to support building coalitions, better facilitating a sense of external community beyond the immediate educational experience. Although social media is becoming more popular with younger audiences, a dedicated platform could support learners in a specific geographic area to connect, share content relevant to the surrounding communities (e.g., their PSA videos), and keep in contact with nearby sources (e.g., the university contacts). Further, since instructors put in great effort to understand learners' particular interests, an online world or platform could also incorporate the ability for learners to publicly (within the program) display their interests and see others' interests as an initial point of mutual connection for a coalition (something instructors' currently have to do, which can take quite a bit of time and may not be as effective in shorter programs).

Lastly, one might consider the intersection of multiple of these themes in their application to technology. For instance, since instructors felt a need to heavily facilitate norms, model behavior, and scaffold learner-learner conversation, chatbots or other virtual agents may be used to assist as a design opportunity. Chatbots in the past have been used to help support social interactions and self-disclosure [36], normalizing differences between learners. In this context, a virtual agent in an online world or learning platform could prompt the learners to chat with one another or model social interaction with others (or alternatively ask the learners to model behavior which will teach the agent the cultural norms and interactions they create for the setting). This approach could build on the work done in the space of virtual peers, utilizing the 'protege effect' which has been found to support learning while enabling ego protection around sensitive topics [11], as well as support positioning learners as tech creators in their co-creation of the chatbot technology.

Throughout the development of new CSCW technologies that support connectedness in culturally-responsive environments, it is important to keep in mind the varying levels of access available to learners, as equity is key to cultivating a sense of connectedness. In general, technology interventions should therefore remain lightweight in terms of apps and devices that are needed.

5.2 Limitations

A main limitation of this work is our lower number of interviewees, due to the modest amount of culturally responsive STEM programs and instructors we were able to reach in the COVID-19 pandemic. However, themes were consistent across four unique programs, suggesting our main themes are robust. Additionally, due to the COVID-19 pandemic, the shift to online learning was sudden, and some instructors felt unprepared initially. With more time to plan and develop online materials, some challenges mentioned may be mitigated.

6 CONCLUSION

Culturally responsive pedagogies illuminate social inequities with problem-posing curricula that foster development of students' critical consciousness. A switch to online learning has forced instructors to become creative in supporting the community building and connectedness that form the essential components of CRC. This work lends insight into how instructors perceive and actively address supporting connectedness in online synchronous culturally responsive STEM and computing programs with diverse learners. Instructors sometimes found methods that support

connectedness in ways that were not previously considered, marking how exploration of online practices can help create solutions that carry back into in-person environments. Furthermore, since it is likely that more online synchronous culturally responsive STEM and computing programs will gain popularity, these findings and the design opportunities they inspired will help inform implementation of programs with similar goals and may also provide a blueprint for other online STEM programs to center and empower learners.

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