"I am a Technology Creator": Black Girls as Technosocial Change Agents in a Culturally-Responsive Robotics Camp

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Abstract

Black girls and women have long been creators in computing spaces. However, much computing education positions Black girls as workers who execute tasks for others' purposes. Our work takes a different approach by positioning Black girls as technosocial change agents who challenge dominant narratives and construct more liberating identities and social relations as they create new technologies. We draw on data from seven Black girls, ages 9-12, who participated in a 20-hour culturally responsive computing (CRC) camp focused on robotics. Using a thematic analysis approach, we explore how these Black girls demonstrate and enhance their technosocial change agency (TSCA) throughout the camp. We identify themes related to how creating technology helps Black girls refine and fulfill their definitions of technical creators and develop agency through technology creation. We discuss computing education and technology design recommendations within the TSCA framework to support learners' emerging TSCA in future CRC programs.

CCS Concepts

• **Technosocial change agency**; • **Culturally responsive computing**; • **Robotics in Education**; • **Computing Education**;

CHI '25, Yokohama, Japan

ACM ISBN 979-8-4007-1394-1/25/04
https://doi.org/10.1145/3706598.3713242

Keywords

culturally responsive computing, technosocial change agency, informal learning

ACM Reference Format:
Chun Li, Jaemarie Solyst, Safiyyah Scott, Gabriella Howse, Tara Nkrumah, Erin Walker, Amy Ogan, and Angela E.B. Stewart. 2025. "I am a Technology Creator": Black Girls as Technosocial Change Agents in a Culturally-Responsive Robotics Camp. In *CHI Conference on Human Factors in Computing Systems (CHI '25), April 26–May 01, 2025, Yokohama, Japan.* ACM, New York, NY, USA, 14 pages. https://doi.org/10.1145/3706598.3713242

1 Introduction

Jada is participating in a robotics and computing summer camp for Black girls. In the camp, learners engage in open-ended robotics activities. On day one, the camp facilitator asks her, "Do you think you are a technology creator?" "No," she said, "A technology creator has to have good experience, but I'm not really an expert". On day three of the camp, the facilitator asked the same question when Jada made some progress on her robot. Jada seems to have gained a bit more confidence, but there's lingering doubt: "No, I am?" On the last day of the camp, when Jada was asked this question again, she proudly confirmed: "Yeah, because I created a robot."

This vignette portrays a real situation between a researcher and a learner in a robotics and computing summer camp. This shows how Jada's image of herself as a technology creator shifted as she created her robot in camp. When she had just joined the camp, she did not consider that she was related to technology creation. At the end of the camp, she recognized herself as a technology creator after successfully creating a robot. This incorporation of technology creation into her identity is related to her development of **technosocial change agency** (TSCA), or ability to (1) challenge dominant narratives, (2) construct more liberating identities, and (3) construct more liberating social relations as (4) create new technologies [4]. Accordingly, in the above vignette, Jada constructed a more liberating identity by seeing herself as a technology creator. Jada's response on the final day of camp challenges or pushes back on the dominant narrative that Black girls are not technology creators. In this paper, we explore how Black girls exhibit and develop the four dimensions of TSCA over the course of a robotics and computing summer camp.

The concept of TSCA was coined by Dr. Kimberly Scott and her colleagues [4], who envisioned culturally responsive computing (CRC) (Scott et al., 2014) [56]. CRC was conceptualized to embed concepts from Black feminism [20] into computing education by centering the identities of those systemically excluded from computing fields, namely girls and Black learners. The TSCA framework was initially developed in COMPUGIRLS [4], a culturally responsive technology program for adolescent girls that examines what happens when teachers and girls engage in this more holistic approach to computing education. Many computing programs have demonstrated that incorporating CRC principles effectively addresses digital disparities by emphasizing intersectionality, fostering innovation, and promoting community development [39, 49, 61].

CRC programs highlight the importance of supporting youth in interrogating their identity in relation to the world around them and understanding the implications of computing for their futures [56, 61]. These programs aim to address gaps in mainstream computer science (CS) education and formal computing camps, which often overlook cultural considerations in the design and primarily focus on technical literacy and competencies, particularly programming, to prepare students for technology careers [5]. While these technical competencies, along with the use of technology, physical computing devices, and performance metrics in CS lessons, are necessary, they are insufficient to foster a sense of agency in technology creation. Instead, we must center learners' identities alongside technical literacies [21, 57]. In CRC education settings, learners are encouraged to contextualize themselves and their goals within their larger community while critiquing existing technologies and creating new ones that address community social issues. Core to CRC programs are discussions of identity and power as they intersect with learners' lived experiences, particularly their experiences with technology. Thus, this paper explores how learner engagement with those constructs might influence their broader TSCA development.

Our work seeks to embolden Black girls aged 9-12 as technosocial change agents in a robotics and computing summer camp. Early technology experiences are crucial in supporting youth in developing their TSCA and empowering them to participate meaningfully in innovative computing technologies [4]. Our work focuses on Black girls, as systemic oppression, namely racism and sexism, shape their CS learning experiences [39, 42]. Additionally, we target the 9-12 age group because early experiences can influence learners' attitudes toward technology, its role in their lives, and their ability to use technology for their goals [36]. We need to specifically study the process by which Black girls develop TSCA and build identities as technology creators in a context designed to address the unique barriers they face in their early experiences with technology. This, in turn, addresses how Black girls' are discouraged from continued agency with technology. However, precisely how Black girls develop TSCA is nebulous.

We chose a robotics and computing camp as the context for our work. The technologies used in these computing education programs are essential because the technology is the vehicle for realizing CRC that can support or undermine Black girls' sense of TSCA [56]. Drawing inspiration from previous CRC programs, we note robots enhanced joyfulness during interactive, project-based learning [2, 7, 39]. We chose the Hummingbird, a kids-friendly robotics kit, as the vehicle in our camp for its fun interaction, open-ended tasks, and self-regulated learning pace [7]. The Hummingbird makes it possible for participants to use various materials alongside computer skills to personalize their goals with respect to the design and behaviors of the robot, customizing the output technology [39, 63]. Connecting programming activities to robots' performance could also give learners an immediate, tangible response to track their progress and the growth of their sense of agency through the creation.

In this camp, we centered Black girls in a technology learning environment rooted in CRC and informal learning norms, providing them with the freedom to express themselves and create authentically [44]. The space to develop in a nurturing environment facilitates the journey from technology consumers to creators, where learners are not relegated to traditional classroom roles and rules. Key elements of this environment included playfulness, freedom to navigate the space as learners wished, cultivating relationships between facilitators and learners, and personalized learning experiences. Within this intentionally designed setting, we observed how Black girls exhibited TSCA.

In this paper, we address the research question: **How did Black girls exhibit their technosocial change agency while engaging in the open-ended creation of a robot within a CRC camp?** This work has three main contributions:

(1) This paper analyzes how Black girls exhibit TSCA in a real-world learning experience centered around technology creation. Specifically, it explores how concepts of agency and power emerge within this context. Our findings reveal that agency and power positively influence learners' engagement in technology creation activities, inspiring and motivating them to develop TSCA.
(2) While a few papers discuss TSCA, to our knowledge, none specifically trace the four dimensions of TSCA—challenging dominant narratives, constructing more liberating identities, building more liberating social relations, and creating new technologies—within the context of Black girls' participating in a CRC camp. Therefore, our work presents an initial investigation into Black girls' TSCA process.
(3) We discuss how elements of the learning environment contributed to our findings related to TSCA. This, in turn, allows us to provide insights for computing educators and CRC program developers about technology selection and curricula design.

Taken together, our work positions learners as technosocial change agents in a technology-learning, creation-focused scenario. This contributes to shifting computing education to consider learners' identities rather than solely technical competencies.

2 Related Work

2.1 Black Girls and Women in Computing

Despite facing racial and gender discrimination, Black women have made significant contributions to the STEM workforce. For example, in the 1940s, Black women worked as mathematicians, supporting space programs for NASA [35]. Yet, Black women remain underrepresented, and their contributions are rendered invisible in the computing space. [46]. According to the 2022-2023 Computing Research Association (CRA) Taulbee Survey, only 2.6 percent of CS PhDs were awarded by Black women, compared to 14.4 percent for White women and 11.4 percent for Asian women in the United States [70].

Intersectionality, promoted by Black feminist legal scholar Kimberlé Crenshaw, reveals the mechanisms behind the structured barriers Black women and girls face in STEM education and careers [25]. In computing education, multiple factors of youth identities (e.g., race, class, gender, and sexuality) interact to shape the various dimensions of Black girls' experiences, ultimately affecting their opportunities and decisions in computing [5]. The combined effects of racism and sexism lead to structural challenges for Black girls at school, which we discuss in terms of pedagogy and classroom experience.

2.1.1 Curricula and pedagogy. The curricula focus of computing education contributes to girls' marginalization in the field. Irani's study of college students who majored in CS indicates that merely focusing on metrics like coding speed, numeric scores, and task competence in today's assessment system for students instead of depth and fluency may mislead girls' perceptions of CS or underestimate their competencies [34]. The irrelevant curricula, which disconnected from learners' interests and real-life experiences, would also especially impact their perceptions of CS. Other researchers have focused on how the non-inclusive mainstream CS curricula and education style differentiate boys' and girls' perceptions of technology and hinder girls' success in STEM and CS. For example, there is heavy reliance on lecturing and information technology applications and a lack of active and hands-on experience [50]. Further, curricula rely on standardized testing to measure and reward individual accomplishments [40]. Finally, teaching in the abstract instead of connecting to relevant social topics can also hinder connection to the field [19]. Though research focusing on younger girls in CS education is still growing, we argue these biases can be addressed by privileging other success metrics and learning outcomes. Our work addresses this by showcasing Black girls' TSCA as an alternative metric of success for computing programs.

2.1.2 Classroom Environment. Like many newborn science disciplines in human history (such as astronomy, physics, medical science, etc.) and even science itself, computing has been perceived as masculine and "hardcore" in classrooms [18, 34]. Goode et al. found that it can discourage girls from dampening their confidence when boys dominate the computer classroom [30]. Recent research conducted a mix of surveys and designed experiments in two suburban school districts in Rhode Island to capture the beliefs showing that most children believe girls are less interested than boys in CS and engineering [41]. Children's perceptions partially arise from the gendered treatment learners receive in the classroom, at home, and online. According to Google and Gallup's study in 2020, [29], boys are 1.5 times as likely to receive encouragement from teachers than girls, 1.7 times as likely to be told by parents that they would be good at computing, and nearly 2 times as likely to see someone like them succeed in CS on social media.

At the intersection of race and gender, Black girls encounter unique obstacles at school that ultimately hinder their academic prospects in CS. 62 percent of Black girls reported that teachers were less supportive of their career interests, while 73 percent of White girls felt supported by their teachers [40]. Morris (2007) highlighted the impact of teachers' differing expectations for girls of color, and Black girls were more likely to be scolded for "supposedly subverting their authority" or not behaving "ladylike" [45]. In Apugo et al.'s recent overview of Black girls' experience in U.S. schools, researchers found that Black girls' inclusion in STEM programs depends on teachers' subjective beliefs about a student's academic trajectory, whereby teachers rely on subjective recommendations that disadvantage Black girls from exposure to advanced technology learning opportunities [3]. Further, the lack of role model representation hurt Black girls' anticipated success in CS. For example, Black girls might rarely see people like them get involved in this discipline at school, such as Black women computing teachers in their surrounding lives and online [17]. Margolis (2017) conducted a case study at a predominantly Black high school in Los Angeles, where a history teacher taught CS due to teacher storage in that district. In this study, the researcher found that CS has been naturally associated with "really, really smart" White and Asian males, and students and teachers widely accepted this stereotypical sorting [40]. Another side effect of the stereotypical portraits of computer lovers or professionals is girls' resistance to being a "geek" or even a "nerd," which they are afraid to be perceived by their peers and communities. However, both the physical and virtual environments of their learning space tend to be decorated with objects and themes associated with "geeky" impressions, like Star Wars, which may lead girls and boys who do not want to resonate with these characteristics to feel a lack of sense of belonging [16, 17].

This overview of mainstream computing and technology education indicates the necessity of introducing CRC to combat systemic oppression for Black girls. In view of these limitations, CRC programs can efficiently supplement formal education and build a comfortable environment outside the classroom, allowing Black girls' values and identities to be centered as assets in the learning environment. Thus, in our work, we focus on the learners by mapping the dynamics of learners developing TSCA instead of tracking their numeric scores.

2.2 A Preview of Promising CRC Programs

Integrating technology into informal learning can significantly enhance the learning experience by making it more accessible, personalized, and engaging [1]. Compared to formal education, the researchers found that informal spaces were helpful for learners' positive emotional experience with computing, especially when

Table 1: Overview of various promising CRC camps, highlighting their participants, goals, outcomes, and key takeaways.

Camp	Participants	Goals	Outcome	Highlight
Bulls-EYE PRIDE or Bulls-EYE [28, 38]; Focused on engineering	Underrepresented minority 7/8th graders, undergraduate engineering mentors, early-career math and science teachers	To explore elements applied in CRC and how CRC prepares program mentors to engage with culturally diverse students	CRP entailed understanding stereotypes and fostering relationships	Participants were instructed to design robots to address social justice issues
GET IT [48]; Focused on career-oriented programming	Middle school and high school girls	To test if the camp increases girls' knowledge, awareness, and interest in IT careers, potential influencers that encourage girls to pursue IT careers	Girls' knowledge of IT careers increased, and they reported greater interest than those who didn't attend the camp; other camps could have positive peer influence on them to consider IT careers	Statistical data analysis indicated girls' attitudes swift pre-camp, after-camp, and between camps continuous year
Raspberry Pi Project [15]; Investigated ways teachers could adapt their teaching to be more culturally responsive	Eight Computing teachers in UK K-12 education	To promote the development of learners' critical consciousness of the world and encourage them to ask questions about ethics, power, privilege, and social justice	After the intervention, teachers were much more likely to introduce student choice (agency) into their classroom practice to facilitate relevant contexts for diverse learners	Highlighted four themes that could serve as a basis for a professional development program for teachers wishing to develop CRC teaching
Digital Mirror Computer Camp for Girls [13]; Focused on mentorship and community outreach	Girls from diverse races and socioeconomic classes	Helping girls build on their strengths to find new, creative, and feminist ways of designing and using computers	Participants have designed and built the Digital Mirror homepage and contributed to the camp blog	Incorporated principles grounded in cyberfeminism and composition for other girls' camps to follow, like emphases on play
Digital Youth Divas [51]; Applied a narrative-centered and blended (in-person and online) learning design	Non-dominant urban middle school girls, with a majority of Black and Brown youth	To examine how narrative stories support engagement. Building community within informal STEM learning environments; To validate what program components, such as narratives, connect to girls' developing STEM-related interests and identities	The narrative in its various forms, including written, video, and imagery, combined with mentorship, provided youth with material resources that supported the girls' engagement and interest development. Participants accepted their roles as contributors and exhibited agency as co-designers of the narratives	It explored how alternative STEM storylines provided counter-narratives that upend more prevalent, stereotypical, positively influence youth's perceptions of themselves and their abilities as domain-specific learners
COMPUGIRLS [57]; Focused on humanizing experiences beyond stereotypical images and empowering both researchers and participants	African American and Latino girls from urban Southwest school districts	To test if girls from urban districts be motivated to become technologists if provided with culturally responsive multimedia activities	Girls gained empowerment with their activities as the technology and research demands increased. At the same time, they maintained a strong sense of commitment to communities, leading to connections	The program introduced digital media to enact a clear social justice agenda to develop girls' consciousness of the link between social justice and technology

the curricula were designed to foster learners' sense of possibility within computing [1, 42, 65]. CRC camps have made significant strides in creating educational environments where learners can build their identity, question the limits of technology, and create more authentic technological expressions. These camps have supported learners in developing their critical consciousness surrounding ethical issues [15], creating digital artifacts for expressing identity [51], or connecting personal strengths to feminist ways of thinking and design [12]. The impacts of such camps are generally reflected in students' changing attitudes and perceptions of computing. For example, Georgia Computes! was a statewide initiative that aligns with CRC principles; its pre- and post-surveys at seven workshops from 2007 to 2008 showed statistically significant improvement in girls' confidence in computing and the likelihood of taking CS courses immediately following the camp [14].

While many such projects are based in the United States, several international initiatives embrace similar principles. In the UK, the Raspberry Pi Computing Education Research team collaborated with the University of Cambridge. They launched workshops with teachers and discussed how schools can develop CRC teaching for a more diverse group of learners [15]. They will launch the same project in Ghana in the future. In Argentina, researchers have promoted mobile learning technology, Stanford Mobile Inquiry-based Learning Environment (SMILE), to enhance more equitable learning due to its portability and lower costs. The research team has considered learners' backgrounds to facilitate exploratory learning, such as composing songs, thereby integrating local cultural elements into the educational process. SMILE has reached over 25 countries, such as South Africa, the United Arab Emirates, Ghana, and Tanzania [58]. An overview of CRC programs can be found in Table 1.

2.3 CRC and TSCA: Centering Students From Systemically Marginalized Backgrounds

As some researchers have discussed equitable STEM education for K-12 learners and its further implications on technology development, a handful of works focused on improving underrepresented and marginalized groups' agency. In these works, culturally responsive pedagogies (CRP), or culturally responsive teaching, was promoted in the 1990s by scholars and educators (e.g., Ladson-Billings 1995) [37], which began emphasizing the importance of building on gendered-ethnic minority students' strengths, such as making curricula relevant to their lived experiences, engaging in ongoing dialogue with students as stakeholders in their education, and revisioning pedagogies to meet student's interests and needs in local, situated contexts. More recently, given the increasing ubiquity of digital technology, CRP was introduced and translated to computing education [56]. CRC is an approach extended from CRP to devising technology support and computer education programs. Meanwhile, researchers and educators implemented CRC in STEM-focused camps, programs, and classes for gendered-ethnic minority learners. As these CRCs provided essential insights and experiences in practice, researchers contended that there were limitations [56]. Therefore, Scott et al. evolved and expanded CRC to reflect these shifts, which contains five tenets: (1) All students are capable of digital innovation. (2) The learning context supports the transformational use of technology. (3) Learning about one's self along various intersecting sociocultural lines allows for technical innovation. (4) Technology should be a vehicle by which students reflect and demonstrate understanding of their intersectional identities. (5) Barometers for technological success should consider who creates, for whom, and to what ends rather than who endures socially and culturally irrelevant curriculum [56].

Based on the CRC principles, Ashcraft C et al.'s work in 2017 further contended existing computing programs' approaches, which were historically insensitive to cultural factors [4]. Their program, COMPUGIRLS, particularly for adolescent girls (mostly in eighth or ninth grade), examines what happens when teachers and girls engage in this more holistic approach to computing education. Their paper focuses on the experiences of two cohorts participating in a CRC program and identifies both the opportunities and limitations in nurturing girls' interest and participation in computing. Researchers explored how CRC programs can empower girls, particularly those from underrepresented backgrounds, to become active agents of change in technology. Inspired by how education interacts with youth to address inequities and social relations (e.g., Willis 1977) [66] in anthropology and critical cultural studies, they introduced social conditions. They shifted focus to girls' interactions with each other and their teachers, emphasizing more sociocultural features in the learning context where girls could demonstrate their emerging abilities as technosocial change agents, as they could explore issues related to identity, power, and technology. Their work defined learners' identities as technosocial change agents, which consists of four dimensions: challenging dominant narratives, constructing more liberating identities, constructing more liberating social relations, and creating new technologies. This work provided insights into designing programs to address barriers facing girls of color. CRC and TSCA have been proven efficient in improving minority learners' learning experience through building their technical identities. However, in prior work, there are limited practices that specifically explored how TSCA's application in the CRC program design impacts minority learners' perception or engagement with CS. While numerous studies have discussed the implementation of CRC programs, few explicitly place learners as technosocial change agents and focus on the impact on their identity dynamics. Thus, aligned with the conceptual belief that students are active agents of their learning and not passive bystanders [6] or knowledge receivers, we introduced CRC to our camp within a TSCA framework for Black girls and centered them as technosocial change agents via technology creation.

2.4 Technology Empowerment: HCI Community's Exploration of Agency

Empowering communities through technology is increasingly emphasized in the Human-computer interaction (HCI) community [55]. The empowerment can take on different forms, depending on the context, audience, and the specific tools involved. Many in HCI started to see technology as a tool with the potential to empower individuals by fostering greater agency [31]. Descriptions of empowerment varied from "sense of agency" [43, 67], "autonomy" [10], or "feeling powerful" [47]. In HCI's definition, the sense of agency refers to the feeling of being in control over actions and their consequences [43]. The agency is most frequently applied to interaction design and often realized through the intentional design of tools that allow users to modify or influence the environment around them [1]. Further, keeping users feeling a sense of agency is one of Shneiderman's eight golden rules for designing interactive systems [59].

Although the concept of agency has been extensively explored in user experience design, it has a relatively limited scope at the intersection of learner-centered education. Recently, HCI scholars have begun bridging agency and learning, emphasizing that scaffolding effective learner agency can improve motivation and learning outcomes. For example, Xie et al. (2020) point out that fostering learner agency within educational technologies—such as interactive simulations—can boost learners' confidence and engagement by giving them control over learning outcomes [67]. In the context of digital learning games, Harpstead et al. (2019) found that students in high-agency conditions could learn more efficiently by attaining equivalent learning gains in less time than their peers in low-agency conditions, and they appeared to have successfully self-regulated their learning [33]. Thus, centering agency as a concept can contribute significantly to understanding learner interactions with technology and measuring their learning outcomes, particularly by redefining how success is framed beyond traditional numbers that reflect technical competency.

Our work focuses on a specific type of agency, TSCA, which specifically targets the empowerment of marginalized communities to use technology for social change and equity. While traditional interpretations of agency in HCI often emphasize individual autonomy or control within a technological system, TSCA is concerned with empowering marginalized communities to leverage technology for social change and equity and connect their creation to the community. Unlike frameworks focusing solely on personal achievement, TSCA aligns and situates agency within a broader sociocultural context [4].

HCI designers explore how to enhance learner agency by applying intuitive, flexible, and responsive technologies as vehicles for the empowerment of learners [23]. However, not all technologies support TSCA equally. Bennett et al. (2023) caution against systems dictating too much of the learning process, limiting learners' autonomy, and reducing their engagement with the material [10]. In contrast, technologies that provide hands-on, personalized experiences—like robotics or engineering kits—are particularly effective in enhancing young learners' agency and making learning more enjoyable [52]. For instance, robot construction kits have been designed for kids to explore new ways to integrate robotics with traditional crafting practices. These robots have a long history and have shown the potential to empower youth by allowing them to be creators of technology rather than consumers [11, 69]. Early robotics toolkits like LEGO Programmable Bricks and GoGo Board-a more affordable variation used in Brazil-have been shown to facilitate engaging learning experiences for youth in informal education settings [52, 60]. When youth are enabled to create and control robots' functions or design their aesthetic features, they take ownership of the learning process and gain authentic constructionist learning experiences. This empowers them to have their robots navigate the world while fostering the development of TSCA [39]. Inspired by the benefits of the robot approach, we integrated Hummingbird robotics kits into our camp to incorporate playful technology creation and support TSCA [63].

3 Methods

3.1 Participants

Aligned with the principles of CRC pedagogies and the TSCA framework, a culturally responsive robotics and computing summer camp for Black girls was held in July 2022. We aimed to frame a landscape for Black girls to develop TSCA and reflect during their technology creation. Our research team collaborated with an out-of-school education organization on the East Coast of the United States that served as a community pillar for predominately Black children and their families for 50 years. This organization provides an educational, recreational, and creative space for learners and focuses on learners' social and emotional development and multi-generational learning. This program was part of a multi-year partnership, where we develop programs, seek funding, and evaluate success as a team with the community partner rather than solely as researchers. Eight participants signed up before the camp, and seven participated in the robotics sessions. On average, five participants attended each day. Between sessions, gym, lunch, and general play time were included. Most learners sat in one cluster of desks to encourage collaboration. There was a desk group of five (like in Fig. 1), but groups of two or three would also split off and work in other parts of the room. A few pairs of learners elected to work in other parts of the classroom.

All participants self-identified as girls (amongst diverse gender options, such as boys or non-binary), with an average of 10.5 years old and in the 5.5th grade. Six learners described themselves as "Black or African American," and one also included "Hispanic." Four participants had previous experience in CS, with three having attended computing or technology classes at school where they learned skills such as computer basics, Lego robotics, or coding before the camp. The remaining girl had experience using smart devices. Two girls responded with "not really," and one girl answered "no" when asked about their prior experience in CS. Table 2 presents their demographic information along with their robot identities.

3.2 Data Collection Procedure

Our program was conducted over five days and was situated within a summer-long program at our community partners' organization. To achieve an informal learning setting, we fostered a relaxed, learner-centered environment in a classroom provided by our partner, including adopting flexible seating arrangements, equitable classroom dynamics, and incorporating playful activities so that learners had more agency over how they chose to learn. Every participant completed the study in person. Sessions were led by our research team, including seven facilitators. The facilitators came from diverse cultural and racial backgrounds, including Asian and White women in undergraduate and master's degree programs and Black women pursuing a PhD degree. Other facilitators include an Asian American woman who was a PhD candidate with a background in designing and teaching inclusive computing curricula for youth and undergraduates, a Black American woman who was a university faculty with a background in CRP and over 20 years of experience teaching STEM topics to middle school students in the United States and Africa, who also led training for the rest of facilitators. The entire research team, including facilitators and researchers conducting data analysis, took part in a multi-day professional development centered on the principles of CRP and offered support to help learners. On each of the five camp days, we had a two-hour morning session and a two-hour afternoon session, totaling four hours per day and 20 hours per week. There were three types of curricular activities: culturally responsive warm-ups, AI fairness, robot creation, and dialogue creation.

Culturally responsive warm-ups were conducted at the start of each day and focused on community building and supporting learners in reflecting on their identity and power. For example, learners played a name game where they shared their names and parts of their identities that were important to them. This was followed up in future culturally responsive warm-ups by defining what identity is and supporting learners in reflecting on how their identity shapes their experience in life. AI fairness sessions, conducted on days one and two of the camp, focused on topics related to AI and bias,

Table 2: Participants' Demographics and Information about their Robots

Participant pseudonym	Age	Race	Prior Experience	Robot
Destiny	12	Black or African American	Activities and a class about learning computers	Cali (girl)
Diona	10	Black or African American	Experience using smartphone, iPad, and Apple watch	Didn't clarify
Femi	9	Black or African American	No	Mariah (girl)
Hawa	10	Black African American	Lego robotics class at school	Karii, formerly Steven (boy)
Panya	10	prefer not to say	Coding class in the 3rd grade	Kayla (girl)
Olivia	11	African American and Hispanic	Not really	Cleo (girl)
Opal	11	Black or African American	Not really	Rob (boy)

Table 3: Robotics Workshop Schedule, detailing the session topics and corresponding activities

Session	Topics	Overview
Session 1	Flow of control, single and tri-color LEDs	Learners discussed how to program LEDs and related it to lights they have seen on TikTok.
Session 2	Rotation and position servos	Using physical actions to describe each concept resonated well with the learners. Demonstrating the actions on Stanley, the example robot, proved to be especially helpful in clarifying the ideas.
Session 3	Sound sensor, loops, conditionals,	Learners mastered the loops to make codes easier to read and write, and they found it easier to combine the concept with sound sensors. Learners found conditionals more challenging to understand due to their reliance on abstract logic.
Session 4	Finishing touches, Robot Runway: to document all the cool things their robot has or does (i.e., TikTok)	The making of the final video was an addition to the curriculum in response to the learners' expressed interest in making videos to share with their friends and family. Learners got to a stopping point and left camp feeling proud and satisfied, with lots of excitement to show off the robot on the Runway.

AI applications, and storytelling for learners to reflect on fair and unfair AI scenarios. As AI fairness is not the focus of this paper, we are committed to analyzing data from other activities.

The remainder of the camp alternated between robot and dialogue creation sessions. Robot creation sessions took place in the afternoons of days two to five, and dialogue sessions took place in the mornings of days three to five. In robot creation sessions, learners were tasked with creating their robot protege, which they would introduce to the world on a Robot Runway at the end of the week. Learners used the Hummingbird robot [63], a kit of lights, motors, and sensors that allows for the open-ended creation of a robotic object. In addition to the robotics kit, we provided craft materials, such as boxes, yarn, or stickers, for learners to create the aesthetic design of their robot. We conducted lessons on hardware and software components needed to develop the robot. An overview of robot creation topics is in Table 3. Robot dialogue sessions focused on getting learners to reflect on how they might want to talk to their robot. They engaged in creative activities and games, such as creating comic strips about dialogue with their robot.

Figure 1: Learners are working with Hummingbird robotics kits gathered around clusters of desks

3.3 Data Processing and Analysis

We employed a qualitative approach to address our research questions. Facilitators actively observed and participated in the camp's activities to interact with learners. Each facilitator made detailed notes on the camp, including that day's activities, what went well, what could be improved for the next day, and some important quotes or paraphrases. We also recorded images and videos of output artifacts from learners, such as images of their designed robots. Finally, we took a semi-structured interview approach to understand learners' experience in the camp [62]. Our interview questions explored learners' work processes, like "Can you tell me what is going on?", their self-perception during the camp "Are you a technology creator?", their interactions in the camp "Who helped you with that?", their feelings "Are you having fun today?", and whether they felt comfortable presenting their work to others "How does it feel when you share your robot with your friends?". We conducted our interview in a relaxed, child-friendly manner and explained the questions when learners did not understand them. We obtained verbal permission from learners before every interview session, in addition to IRB-approved assent and consent procedures.

All responses were audio recorded and transcribed after camp. Researchers conducted a thematic analysis of the interview transcripts, artifacts learners built [54, 68], and facilitator reflections and notes. Four authors led a hybrid open coding [22]. Two of them initiated an inductive open coding by organizing it chronologically and breaking it into smaller conversational units. Then, they labeled these units with descriptive codes that captured their essence. The other two authors conducted a deductive coding approach: they reviewed the codes, and once the team reached a consensus on data saturation [27], they incorporated the TSCA framework to structure the analysis and discussion further. The framework was divided into four dimensions — challenging dominant narratives, building liberating identities, constructing liberating social relationships, and creating new technology. Using these dimensions, they refined the analysis into four corresponding themes and clustered the codes accordingly [4].

The team engaged in collaborative discussions to refine the codes and themes, ensuring alignment with the framework and clarity in interpretation. To highlight the dynamics of bridging between individuals and the community and the development of agency, the team decided to present the findings under two main categories: (1) Creating technology helps Black girls refine and fulfill their definition of technical creators; (2) Helping, being helped, creating, and sharing - elucidating the factors that influenced Black girls' agency. In the discussion section, we position our findings within the context of the TSCA framework, mapping the themes back to its four dimensions.

4 Findings

4.1 Creating Technology Helps Black Girls Refine and Fulfill Their Definition of Technical Creators

4.1.1 Girls set up an impossibly high standard of technology creators in their initial definition. One of our interview questions was, "Are you a technology creator?" This question was routinely asked on three out of five days: the first, third, and the last day, to monitor changes in girls' understanding and definition of technology creators. At the earlier stage of the camp, girls tended to set an impossibly high standard for anyone to be a technology creator. They contributed a series of factors making someone a technology creator: "producing electronics products, like TV and phones, all independently" (Femi); "working in high-tech companies and has the power to design, like Apple" (Hawa); dressing like a character in sci-fi movies and has to "wear glasses and a vest, and they are tall, with blue hair" (Opal); knows "hacking" (Destiny); or "knows what to do with anything, and technology" (Opal). When we asked them to define what makes a good technology creator or a bad technology creator, they became even stricter: "Doing it every day" can make you a good technology creator, and "not keeping stuff in order" makes someone a bad technology creator (Femi). Often, beyond setting extremely high standards, the definitions were vague. For example, Hawa said, "Technology involves science" without giving more details. Despite engaging in coding and assembling electronic components, learners considered themselves far from the technology and excluded themselves from being technology creators. Similarly, they initially didn't include anyone they knew as a technology creator, presumably because people they knew did not match this standard. When asked if anyone in the room was a technology creator, Panya, Opal, and Olivia, who responded to the question, all answered no.

4.1.2 From Apple to my community - technology creators are people around me. On the third day, when we asked them the same question again, girls started to include someone they knew in their definition of technology creators. When we asked girls to name someone specific, their answers shifted from vague concepts to real people. For instance, Hawa initially thought of people at Apple as technology creators, which was then refined to specific people around her. She mentioned Ms. F, one of the staff members at our community partner, who directs after-school programming and worked with us to create the program discussed in this paper. Similarly, Diona recognized one of the facilitators as she "is the one who basically taught us all the steps we need to build the robot." Olivia's definition of technology creators was unclear at the early stage of the camp, and she did not initially recognize anyone as a technology creator when we asked her to give some examples. However, later in the camp, this shifted as she identified her teachers as technology creators. Diona mentioned her mom, who worked for a "telephone company" as a technology creator because she "has studied hard."

In addition to including adults with technology careers, learners began to notice their same-aged peers. For example, Destiny, Hawa, and Diona were recognized by other learners as technology creators. Their peers likely recognized them as technology creators because they built visibility by sharing creation and knowledge with peers. Destiny shared her solution with other learners and helped their robots move better. Hawa was excited to get up in front of the room and show off her work. Diona thoroughly explored the coding interface and introduced coding blocks to others that even the facilitators had not yet explored.

4.1.3 Through creating robotics technologies, Black girls expanded their definition of technology creators to include themselves. As the camp progressed, learners shifted from their high and vague standard of technology creators to people around them, eventually including themselves. Gradually, they aligned what they had just done to their refined definition of technology creators. For example, Destiny first recognized one of our facilitators, who taught girls about robot hardware as a technology creator. After she figured out a strategy to adjust the robot's motion and shared it with the group, she included herself as a "kind of" technology creator because she had achieved the same thing that fit her definition.

Although girls initially set nearly perfectionist standards, they gradually refined their expectations as they progressed and gained a more nuanced understanding of technology creation. Opal believed that good technology creators "need to have a lot of experience," and her identity did not match her initial definition: "A technology creator knows how to fix anything and knows what to do with anything, any technology." However, as she progressed, she began to recognize herself as a burgeoning technology creator (e.g., by answering "a little bit" when asked if she was one). She also noted that her creation was just "a box moving was a cup head." Indeed, multiple learners grounded their newfound definitions in the activities they had just done. For example, Destiny thought of "hacking" when she was asked to think of one characteristic of technology creators, and it became "creating electronics" in the later session, which is closer to the specific activities of the camp. Femi valued the final physical products, noting technology creators would be able to create laptops, TVs, computers, and phones. She added "robots" to this category of what technology creators produced after she made progress on her robot.

On the fifth day they worked on the robots, we asked learners the same question for the last time, and most of them confirmed they were technology creators. Six out of seven girls identified themselves as technology creators at the end of the camp. Among these six girls, two girls, Olivia and Opal, shifted their answers from not being a creator in the beginning to a technology creator after they created a robot. The remaining learners' definitions of technology creators became more specific, incorporating the tasks they performed in the camp. Taken together, through the process of creating robots, learners shifted their perception of technology creators from vague, unrealistic standards to eventually include those around them and themselves, as well as the types of creations they produced.

4.2 Helping, Being Helped, Creating, and Sharing - Elucidating the Factors that Influenced Black Girls' Agency

4.2.1 Accepting help weakens Black girls' sense of agency. However, helping others strengthens it. Learners were cautious about accepting help during the camp, including from facilitators or peers. Not accepting help or accepting as little help as possible was considered an achievement. On the last day of the camp, Panya proudly said she was a technology creator because "I just built this without most of the help." Opal gave a similar reason, saying she was a technology creator "because I made it all by myself, and the fact that it moves around made it really do that." Conversely, accepting help meant the learners questioned their capability to create technology independently, especially after the camp concluded. Olivia doubted her capability to reproduce the robot: "No, because I got a lot of help." Hawa also noticed the impact of the help on her work and was "not sure about working...without any help" after the camp.

Destiny is particularly exemplary of this giving versus receiving help dichotomy. With lots of trial and error, Destiny figured out a method for adjusting wheel speed until the robot drove in a straight line. She shared this thought process with others, who then used her strategy to stop their robot from continuing to drive in tight circles. Despite making this engineering breakthrough, she still expressed concern about accepting help: "They taught me how to build. If I build something like just by myself, electronics or something like that, I would be proud of myself." That said, Destiny was excited to help others, noting, "It was fun because I was able to help other people." Other learners in the camp saw Destiny as a technology creator, saying, "Because she already has a sound server and she's almost done" (Hawa). However, despite all these reflections on her status as a technology creator, Destiny insisted that she was just a "kind of" technology creator on the last day because the facilitators had also helped her. She didn't believe she could build a robot after the camp either because "... other people helped me... I didn't build it myself."

Learners tend to define those who have helped them as technology creators or "smart," like teachers and some of our facilitators who led the robotics teaching. They considered teaching and helping others to be characteristics of technology creators. Three girls, Femi, Hawa, and Destiny, recognized teachers and facilitators who walked around and guided learners as technology creators. For example, Femi identified a facilitator who led the robotics session because "she's helping us and making the robot."

Although the girls initially appeared sensitive about collaborating, which might have reduced their sense of freedom and confidence as independent technology creators, they gradually adapted to the informal learning environment. Over time, they became more confident and began to enjoy equitable relationships with the facilitators. We observed a phenomenon of "power switch" in which learners interviewing instructors: Diona (with help from Femi, who was the "camera person") wanted to interview facilitators in the content creation corner toward the end of the session. She was very official, using a stack of papers that she wielded in a very officious manner and interviewing them like she was the teacher while Femi recorded them.

4.2.2 Black girls demonstrate their agency by creating, controlling, and sharing their robots. Building and controlling robots allowed Black girls to realize autonomy and influence. In response to our question on the second day, "Does creating a robot make you feel powerful?" three girls, Hawa, Femi, and Olivia, said yes. Hawa expanded on this by saying creating her robot made her feel powerful "by motivating me to be good and cheer." Learners were especially empowered when they felt they could control their robot to fit their goal through programming. For example, Hawa expressed a strong desire to control her robot, using the word "control" many times. In response to the question, "What are you working on?" Hawa said, "My robot is kind of a controlled robot," "She moves everywhere you tell her to go," and "She's controlled by me."

Creating a robot that was similar to them was a primary method for exhibiting this control. All learners mirrored elements of their

Figure 2: Learners' final products and our example robot. From left to right: Olivia's robot, Cleo; Femi's robot, Mariah; Destiny's robot, Cali; Hawa's robot, Karii; Panya's robot, Kayla; Opal's robot, Rob; our example robot, Stanley

own identity in their robot creations, including hairstyles, fashion choices, and interests. They valued the aesthetic design of their robots using art supplies like markers, stickers, and yarn. For example, Destiny designed her robot to have a bun and black clothing, mirroring her own style choices. Femi also added a ponytail with pink ribbons to her robot to match the pink ponytail that she wore. Some girls also created background stories and personalities for their robots based on their experiences. For example, Panya added a headband and a purse to make her robot, named "Kayla," look fashionable because she is "fashionable." Destiny changed her robot's name to "Cali" because she always wanted to go to California. Femi likes swimming and puts many animal stickers on her robot, named "Mariah," because "she lived in the Ocean." Olivia's robot, "Cleo," has a favorite color, blue, which is also her favorite color.

In addition to creating and controlling their robot, sharing their robot creations also contributed to Black girls' sense of agency. Olivia felt powerful and excited when "sharing my robot with everyone and showing what I created," adding, "Because I want other people to be inspired by it." Similarly, Destiny said: "I want to share this with people who want to know about robots." Hawa wanted to share with people who "don't get the chance to make things." Beyond personal expression and community building, Olivia also linked sharing to career endeavors, citing social media content creation as a financially beneficial path. She emphasized that sharing is "important" because "it can make a lot of money." At the same time, some learners were cautious about the audience with whom they shared. For example, Opal wanted to share the video of her work, but only with people "I trust and might give me some good encouragement, and they don't laugh at it." She highlighted how agency can fuel motivation: "They will tell me to keep going, and I will be better at it-the more I do it." Taken together, the ability to design and control their robots, including infusing them with personal elements and backgrounds and the act of sharing their creations, were crucial to Black girls' agency.

5 Discussion

We analyzed interviews, artifacts, and field notes to uncover themes related to the Black girls' technosocial change agency (TSCA). Here, we will map our specific themes into the four dimensions of the TSCA framework: challenging dominant narratives, building liberating identities, constructing liberating social relationships, and creating new technology. We discuss how our work can be applied to create culturally responsive computing (CRC) education programs and technologies that support learners' TSCA. Importantly, as noted in Section 2.4, the HCI community defines agency as the feeling of control over actions [43]. However, we focus on a specific type of agency, TSCA, because of its emphasis on individual and community change through technology creation.

5.1 Black Girls Challenge Dominant Narratives to Build More Liberating Identities

Through the camp, we found that Black girls expressed challenges to dominant narratives by redefining what it means to be a technology creator. When initially asked about what it means to be a technology creator, learners' answers were connected to dominant narratives about technology creators being entrepreneurs and the "rock star" programmer [26], often associated with wealthy companies. They also described the dominant imagery of technology creation, focusing on how it is a solitary and stereotypically nerdy profession that may also reinforced by the media and their experience [19]. As girls gradually modified the initial impossibly high standard of technology creators and built their TSCA, the distance between them and technology creators gradually narrowed until they met the refined definition. First, they included teachers, facilitators, and parents in this definition. Then, they mentioned their peers. Finally, they claimed they were technology creators by creating a robot. Further, their definitions of a technology creator got more specific, moving from vague notions like creating phones and TVs to specific people they knew and tasks they completed.

This attitude shift provides evidence that engaging learners in open-ended technological creation strengthens their identities as technologists and influences their perceptions of who can create. By increasing the joyful experiences in "creative production" [9], learners could visualize, connect, and overlap themselves with those concepts that used to be far away from them. In related CRC programs, researchers noticed the positive impact of joyfulness on the learning process, for example by positioning learners as co-creators with robot technology [39], engaging learners in a narrative storyline that is based on non-stereotypical characters, like racially and ethnically diverse middle school girls [51], or introducing hands-on STEM activities and experiments in [53]. Mainstream computing curricula, however, often lack such cultural relevance to Black girls and do not make space for them to challenge dominant perceptions of the field [19]. The creative process, in contrast, can be a space for learners to investigate and refine technological concepts. As Black girls began challenging dominant narratives about what technology creators and creations look like, they started to build more liberating identities. The component of liberating identities in the TSCA framework refers to learners' technical and cultural identities. Building technical identities has positive long-term dynamics on how and what kids learn [12]. When learners develop identities as technologists, they tend to be more confident that they can master STEM knowledge and techniques in the future [32]. CRC camps can foster an environment for learners who do not have many chances to build technical identity in formal education scenarios to thrive [5]. Our findings demonstrate that Black girls built or strengthened their identities as technology creators by participating in the rich, open-ended robot creation tasks. Learners set their own goals for their robots and learning pace. They were not required to apply all the skills they learned, but they had the freedom to customize their approach based on their goals.

5.2 Black Girls Challenge Dominant Narratives to Build New Technologies

Creating new technology in the TSCA framework carries both technological and social meaning. It is important to support learners in reflecting on the ways that their creation can influence their community and society more broadly. The phenomenon of learners being willing to express themselves via technology creation was evidenced in our camp. Another example of challenging dominant narratives is reflected in the learners' final robots. In the camp, we provided art supplies for them to decorate their robots, and they contributed artistic expressions and innovative endeavors, which are essential parts of today's creative technology. As technology innovations mirror creators' values and beliefs, Black girls' robots reflect numerous Black feminine cultural elements, especially hairstyles. Hair is far more than just a physical attribute for Black women and girls but a historical heritage of Black cultural pride and personal identities; it symbolizes resistance, creative expression, and freedom [64]. This is not commonly depicted in mainstream media or education about robotics. Not only does this show their challenging dominant narratives of whose image technology can be created, but it also showcases the ways Black girls create new technologies they have not seen before. Thus, we saw emerging efforts of Black girls to incorporate aspects of their own identity into their robot creations, often explicitly reflecting that they wanted to create a robot that was like them.

5.3 Black Girls Construct More Liberating Social Relationships

We observed a bi-directional relationship between individualism and communalism. As learners began to view themselves as technosocial change agents, they became empowered to break down barriers within their community by sharing knowledge with peers and challenging dominant narratives on behalf of others. For example, we observed that Destiny individually identified a strategy for robot motion difficulties and helped her peers resolve similar problems (individual to community). Her community also celebrated her contribution and identified her as a technology creator (community to individual).

That said, there were still limits to this - for example, Destiny viewed her identity as a technology creator as limited because she received help from others. Our findings suggest that learners initially tended to see themselves as more agentic technology creators if they primarily worked independently. Conversely, accepting help from others appeared to risk undermining their confidence in their technical abilities. Their emphasis on independence might be influenced by social factors in U.S. education style and American culture, which often strongly emphasizes individualism over collaboration and rewards individual accomplishments rather than community [40]. Moreover, traditional CS pedagogies have not typically encouraged collaboration [8]. By comparison, the camp fostered communication, group discussions, and idea-sharing, allowing Black girls to collaborate on robot design and building while strengthening community bonding. As the camp progressed, Black girls began to embrace collaboration and found joy in creating technology as active members of the community.

5.4 Applications to Technology and CS Education

Our findings pertain to the ways Black girls exhibit TSCA in a CRC robotics program and the theme of TSCA can positively impact learners' engagement in technology creation activities. Seeing the influence of their actions on the robots, especially motivated learners when that aligns with their goals, or thereby assessing their strategies. Beyond technological skills, learners need to be equipped with advocacy skills to create new technology that can foster more significant equity. In future CRC programs, CS curricula and technology can be designed to support TSCA. We propose the following design guidelines for others doing work in this space:

Introduce open-ended tasks at a self-regulated pace to help build learners' confidence in their technical identities. Providing space for personalized expression and customization while creating technology allows learners to connect with self-expression concepts that might be important to them (e.g., fashion styles, hair aesthetics). By selecting appropriate approaches that allow for self-expression, tools can contribute to learners' recognition, expression, and construction of their cultural identity. For example, our task was open-ended and encouraged learners to create their robot protege. We provided a variety of materials that learners used to mimic their cultural hairstyles and textures, thus creating new technologies that were affirming to them.

Encourage learners to reflect on their cultural backgrounds, identities, and aesthetic expressions. This may mean that learners create products that differ from mainstream technologies, which should be both recognized by facilitators and encouraged. Robotics was a particularly useful vehicle for this because of the ease of creating humanoid-like artifacts. Learners were able to explore physical manifestations that were reminiscent of their own identity and aesthetic expressions. This could be accompanied by storytelling activities that support learners in reflecting and critically analyzing existing technologies and their own in order to create more inclusive narratives.

Scaffolding collaboration with peers can support learners in challenging dominant narratives and constructing more liberating identities. When learners successfully helped others solve issues, they increased their self-concept as technologists. The peer influences and role model effect also positively affect the group dynamics [24]. Seeing someone similar to themselves creating and solving technical problems can help challenge dominant narratives of who belongs in computing spaces. In CRC programs, strategies like recognizing achievements, peer teaching, and group projects can be introduced to empower learners. However, these collaborations need to be scaffolded. Learners who received help minimized their creations despite all technologies being created as a result of collaborative processes. Reflective activities could support learners in exploring how their favorite technologies are built and showcase the wide variety of roles and expertise needed to create any product. This peek into the technology creation process could be supportive in disrupting learners' narratives that they must independently create something in order for it to be considered an achievement.

The physical environment should be intentionally constructed to support collaboration, such as through flexible seating arrangements and shared workspace. This upends the expectation of who is giving and receiving information. For example, arranging desks in a way that learners all face the front and are independent encourages them to count on the teacher as the source information. Thus, collaboration can dismantle classroom hierarchies between who is the teacher and who is student.

5.5 Limitations and Future Work

This work represents one of the first attempts to apply the TSCA framework in the CRC camp. We recognize some limitations in our work, which can be addressed in the future. First, our camp size is relatively small (N=7), which fostered a more intimate environment where we could deeply reflect on how to support individual students' needs. Still, this limits the generalizability of the findings, indicating further work needs to be done to validate findings on a larger sample size. Second, some learners knew each other before attending the camp; for example, girls might intend to pair up with someone they know to work and share their strategies with friends, which might influence their interactions and collaboration. Therefore, further work is needed to explore how collaborations emerge as the population differs - for example, with learners who do not know each other versus learners with prior friendships. Finally, our work is exploratory in nature, focused on understanding and describing Black girls' TSCA, not attributing causation. Thus, we cannot determine causation between our summer camp intervention and Black girls' budding TSCA. This also limits claims of when, for how long, and the conditions under which Black girls' TSCA emerges. Future work could include a longitudinal, experimental study design that clarifies these points. Nonetheless, these limitations do not detract from the overall contributions of TSCA's practice in the real world. Future studies with larger, more diverse samples and longitudinal designs will help to address these limitations and deliver more findings with broader applicability.

6 Conclusion

This work applies the technosocial change agency (TSCA) framework to a culturally responsive computing (CRC) robotics camp. We positioned Black girls at the center of our design and analysis to explore the dynamics of the process of learners exhibiting the TSCA through technology creation activities. Through the camp, Black girls actively engaged in open-ended creation activities and delivered robots they created as the final products. Our findings indicate that involving learners in creating technology in an informal learning environment would help accomplish TSCA and thus support the goals of CRC. We connect our discussion to the four dimensions of TSCA and provide suggestions for future CRC camps and CS curricula design.

Acknowledgments

We sincerely appreciate all the learners who participated in this CRC robotics camp, as well as the dedicated staff of our partner organization. This work is funded by NSF DRL 1811086, DRL 1811610, and DRL 2315042.

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