



Centering teacher and parent voice to realize culturally relevant computational thinking in early childhood

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ABSTRACT

The specific mechanisms by which teachers and parents can provide culturally relevant opportunities for computational thinking for racially/ethnically and linguistically diverse groups of preschoolers remain unknown. Accordingly, the purpose of this research is to examine how PreK parent and teacher voice directed efforts to realize a culturally relevant computing program. We drew data sources from a subsample of design-based research meetings in which partners collaborated to co-develop the first iteration of the program. Using qualitative analysis, we examined how parent voice and teacher voice, conceptualized as perspectives and participation, influenced theories of culturally responsive computing and computational thinking in early childhood education and the translation of theory into practice in classroom and home settings. Findings showed that connecting powerful ideas from computational thinking, namely algorithms and problem solving (e.g., debugging), to familiar activities and experiences served as a powerful entry point. Yet, differences arose in how teachers and parents conceptualized culturally relevant computing and made connections to familiar routines. We discuss what can be learned from parent voice in regards to bolstering children's self-expression, access to increasingly complex computational thinking tasks, and opportunities for learning cultural and community values through computing.

Computer science education can help realize a range of educational and social goals, including workforce development, social innovation, civic engagement, and equity (Vogel et al., 2017), but to remedy the pervasiveness of inequities and racist practices within computer science, asset-based perspectives and culturally relevant approaches are necessary to support the learning and development of BIPOC¹ students (Leonard et al., 2022; Madkins et al., 2020). Despite promising models in K-12 (e.g., Eglash et al., 2013; Jacob et al., 2018; Lee et al., 2015; Zhang & Nouri, 2019), pre-kindergarteners have largely been overlooked in “computer science for all” (Smith, 2016) initiatives. Young BIPOC children express a strong interest in computer science, and their parents and caregivers² often encourage pursuit of a career in computer science (Wang & Moghadam, 2017). Yet, BIPOC preschoolers from multiple language communities rarely gain access to toys or tools that encourage

science play (Gerde et al., 2021), which can promote computational thinking. When children enter school with such learning opportunity gaps, those gaps only continue to grow wider throughout elementary school (Chaudry et al., 2017), and the same should be regarded for computer science education.

Because PreK parent engagement and at-home learning relate to children's overall school readiness (Barnett et al., 2020), PreK computer science education requires the involvement of both PreK teachers³ and parents. Meanwhile, the specific mechanisms by which teachers and parents can provide asset-based, culturally relevant opportunities for computational thinking across school and home settings remain unknown. Thus, program development must center teachers' and parents' perspectives and funds of knowledge (González et al., 2005). Accordingly, the purpose of this study is to examine how PreK parent and teacher voice

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¹ BIPOC stands for “Black, Indigenous, and People of Color.” The term is used in North America to challenge indigenous invisibility and anti-Blackness and to advance racial justice (The BIPOC Project, 2016).

² Henceforth, we use “parents” to mean any caregivers who serve in a parenting role.

³ We use “teachers” to refer to licensed PreK teachers and teaching assistants/educational assistants.

directed efforts to bring a culturally relevant computing program to BIPOC children's homes and schools. More specifically, we considered how parent and teacher voice provided the foundation for building theories of culturally relevant learning and computational thinking and translating those theories into practice.

1. Early childhood computer science education

A burgeoning body of research seeks to examine the impact of computer science education in early childhood. A recent systematic review of research on programming in early childhood found thirty-four relevant studies (Macrides et al., 2022). Studies have focused on a variety of tools in early childhood, including electronic gaming platforms (e.g., Aladé et al., 2016), coding and programming (e.g., Lee & Junoh, 2019), and robotics education (e.g., Sullivan & Bers, 2016). Researchers largely agree that tangible technologies, which allow for physical input and manipulation, or unplugged activities, which do not feature computer involvement, best support young children to create programs and debug them (Lee & Junoh, 2019; Macrides et al., 2022). Moreover, young children also benefit from building foundational understandings of how the technology they use routinely works (Martinez et al., 2015). Across approaches, computer science education in early childhood is most often guided by a Positive Technological Development framework, which integrates computer science learning opportunities with other activities (e.g., music, dance) to promote positive interpersonal development (Macrides et al., 2022). Translating this framework into practice is guided by four key dimensions (Bers & Sullivan, 2019): (1) conveying powerful ideas from computational thinking; (2) promoting self-expression, (3) differentiating for novice engagement and increasingly more complex tasks, and (4) practicing and prompting debugging (i.e., children identify problems and solve them).

Computational thinking (CT) is recognized as a critical 21st century skill and the primary skill necessary for becoming creators, rather than consumers, in our digital world (Wing, 2006). Different conceptualizations exist, but in early childhood computer science education, CT is generally comprised of distinct but interrelated concepts, namely, algorithmic thinking, debugging, pattern recognition and generalization, and modularity (e.g., Bers et al., 2019; Lavigne et al., 2020). The key to CT is using algorithmic thinking, patterns, and sequences to solve problems. CT is central to and associated with thinking across STEM disciplines (Bers et al., 2019; Wing, 2006) and beyond (Wing, 2008). Research examining how CT develops in young children is relatively limited; however, it demonstrates that preschool-aged children are able to learn and practice coding skills leading to increased CT (e.g., Angeli & Valanides, 2020; Elkin et al., 2016; Kazakoff et al., 2013; Lavigne et al., 2020).

2. Culturally relevant computer science education

Cultural stereotypes and, consequently, limited CT learning opportunities maintain gender inequities in computer science (Bian et al., 2017; Funke et al., 2017; Master et al., 2016), but considerations of early socialization and access among BIPOC children from multiple language communities remain underexplored. In fact, the needs of BIPOC children have been largely ignored (Newton et al., 2020). Equity-centered approaches to computer science education can broaden participation in computer science while also empowering students “to integrate their computer science knowledge with efforts to solve issues relevant to minoritized communities” (Madkins et al., 2020, p. 6). A range of equity-centered approaches exist, such as culturally relevant pedagogy (Ladson-Billings, 2009), culturally responsive teaching (Gay, 2018), and culturally sustaining pedagogy (Paris & Alim, 2017; for an elaboration of differences see Aronson & Laughter, 2016; Madkins et al., 2020). Generally, these culturally relevant education approaches leverage cultural and linguistic resources, knowledge, and experiences from BIPOC students' homes, families, and communities as assets (i.e., funds of

knowledge; González et al., 2005) in supporting student learning to alleviate social and structural barriers. Bringing these ideas into computer science education, Scott and colleagues (2015, p. 420–421) proposed the following principles for culturally responsive computing (CRC): (1) “all students are capable of digital innovation” when they have opportunities to learn about themselves; (2) learning can support “transformational use of technology” (i.e., stretch/explore boundaries of what computer science can do); (3) computing is a “vehicle by which students can...demonstrate understanding of their intersectional identities” (i.e., confront and critique stereotypes about race, gender, and class that position them as not belonging); and (4) success considers “who creates, for whom, and to what ends” (i.e., challenges socially and culturally irrelevant curriculum).

Despite the positive impact of culturally relevant education on student outcomes (Aronson & Laughter, 2016), few studies have taken up cultural considerations in computer science education. A recent review of literature identified only twenty-two studies that addressed culturally relevant education in computing, and none of those studies took place in early childhood contexts (Morales-Chicas et al., 2019). Synthesizing across studies suggested six strategies for CRC in K-12, including raising sociopolitical consciousness and leveraging funds of knowledge, such as cultural heritage artifacts, vernacular culture, lived experiences, community connections, and personal connections. Additional studies suggest that robotics provides an especially powerful approach to CRC for late elementary and middle school students. In particular, robotics offers an authentic way for teachers and students to draw on cultural capital and a sense of place (Harper et al., 2021; Leonard et al., 2018), which shows promise of increasing BIPOC students' sense of belonging in computer science (Leonard et al., 2016; 2019; Newton et al., 2020).

3. Early childhood teacher learning through curriculum development and implementation

Positioning teachers as outsiders in choices about educational curriculum or programming was deemed outdated over fifteen years ago (Carl, 2005), yet is still common practice. Curriculum adoption is increasingly influenced by accountability in test scores and associated funding streams that have pressured administrators to take control of academic programs (Pepper, 2010), even in early childhood classrooms. School districts often utilize a top-down approach to curriculum implementation that reduces teacher agency, confidence, and commitment (Molapo & Pillay, 2018). When teachers' voices are minimized or ignored, curricular initiatives can become disconnected from daily classroom experiences, ultimately contributing to inconsistencies and errors in implementation (Baş & ŞENTÜRK, 2019).

Empowering teachers as active participants in curriculum design and pilot implementation, and subsequent research, transforms daily classroom experiences into key learning moments and problems of practice (Institute of Medicine and National Research Council, 2015; Ziechner, 2003). The authenticity of these classroom experiences is particularly important as teachers develop pedagogical approaches aimed at effectively implementing early childhood CT programs (Camilleri, 2017). Camilleri's early childhood teacher learning-training framework, grounded in key tenets of Activity Theory and project-based learning, identifies how teachers' repeated experiences implementing robotics within familiar classroom contexts increase iterative dialogue and opportunities for teachers to learn alongside colleagues within teacher circles. Critically analyzing and reflecting on these moments through discourse, in collaboration with university partners and families, extends learning opportunities even further as teachers co-construct local knowledge (Geertz, 1983) about how to foster young children's CT in asset-based, culturally relevant ways (Chalmers, 2018; Madkins et al., 2020). Such collaborative approaches are essential given the limited research on teacher education for CRC exclusively focuses on middle and high school teachers (Goode et al., 2020; Leonard et al., 2018). Collaborations designed and facilitated equitably

with BIPOC families from multiple language communities can cultivate “collective transformative agency and community self-determination” (Ishimaru et al., 2018, p. 53).

4. Parental engagement in early childhood education

Parents play an important role in nurturing an interest and sense of belonging in computer science because children’s endorsements of cultural stereotypes are based on their perceptions of the beliefs of all the adults in their lives (Copping Kurtz-Costes et al., 2013). Encouragement from both teachers and parents is correlated with interest in computer science, and parents play an essential role in children’s persistence in STEM across PreK-16 (Wang & Moghadam, 2017). Thus, we expect the same would hold true for computer science education specifically. Moreover, towards equity goals, there is a critical need for BIPOC families to contribute to culturally responsive school initiatives where they can voice their thoughts and influence positive changes (Kayser et al., 2021).

Parents become involved with schools in different ways, but parent engagement in children’s learning has a greater impact than their involvement in schooling activities (Emerson et al., 2012). In early childhood education, however, parents most frequently get involved with schooling, for example, by volunteering in classrooms or attending parent meetings (Castro et al., 2004). These forms of parent involvement may open doors for increased parent engagement in home-based learning, such as reading (Barnett et al., 2020), but BIPOC parents from multiple language communities face unique challenges to involvement in schooling. Namely, they may feel less welcome, struggle to communicate with school staff, hold different expectations for engagement than school partners, or have schedules that conflict with involvement opportunities (Castro et al., 2004; McWayne et al., 2013; Nissley, 2020; Rattenborg et al., 2019). Given numerous barriers to involvement in schooling and the comparative benefit of engagement in learning, prioritizing and supporting parent engagement in home-based learning holds promise for making the largest impact on both child and parenting outcomes (Jeon et al., 2020). Parent engagement that increases home-based learning can bolster overall school readiness, as well as emergent numeracy and literacy, social-emotional learning, and motor development (Barnett et al., 2020; Rey-Guerra et al., 2022). For BIPOC families from multiple language communities, engagement in home-based learning may serve as a more accessible gateway to involvement in schooling. Towards equity goals, however, invitations for school involvement should prioritize type five of Epstein et al.’s (2019) well-known framework. Namely, involvement should position parents as decision-makers in school affairs through parent leaders and representatives. In order to establish equitable leadership that genuinely represents the views and perspectives of BIPOC parents from multiple language communities, this involvement must be coupled with actions to remove the systemic and local barriers BIPOC parents face on a daily basis. Thus, efforts to engage parents should prioritize parent voice in decisions about both school-based and home-based learning.

5. Material and methods

The current study draws from material and methods of a larger project, *Culturally Relevant Robotics: A Family and Teacher (CRRRAFT) Partnership for Computational Thinking in Early Childhood*, with the primary objective of creating a culturally relevant computing program that supports computational thinking and a sense of belonging in computer science among BIPOC preschoolers from multiple language communities. The program was co-developed by a university team, instructional coach, teachers, and parent representatives, using an iterative approach that included the design development, formative evaluation, testing, revision, and retesting of computing and computational thinking learning activities in classrooms and homes (Bradley & Reinking, 2011; Cobb et al., 2003; Nieveen & Folmar, 2013). Design-based research

(DBR) methodology was used to guide the implementation of interactive cycles of development and testing to evaluate the culturally relevant computing program while simultaneously strengthening the program. DBR’s interactive processes allow educational researchers to design and develop interventions and programs that address classroom problems and produce a theory that guides the design to improve teacher practices and students’ learning outcomes (Anderson & Shattuck, 2012). In CRRRAFT, the DBR methodology provided a framework for university researchers, parents, and teachers to collaboratively build a practical theory of culturally relevant computing in early childhood and increase the impact and translation of research to practice.

The vision and leadership for CRRRAFT grew from longstanding university-school collaborations focused on supporting (prospective) teacher development and PreK students’ opportunities to engage in STEM education (for an example see Harper et al., 2021). As the CRRRAFT partnership formalized, the emphasis narrowed to computer science education and the collaboration expanded to include, more intentionally, teachers and parent representatives.

6. Participants and setting

At the time of the current study, CRRRAFT team members included four university researchers, a postdoctoral fellow, and three graduate research assistants across STEM education, early childhood education, and computer science; a Title I preschool instructional coach; two principals; six preschool teachers; two educational assistants; one after school director; and seven parent representatives. University researchers selected two Title I public schools, Dorothy Vaughan Preschool (DVP) and Luis van Ahn Primary School (LVAP) (all names are pseudonyms), located within the same district in a small urban area (population ~200,000) in the Southeastern United States, as sites for launching the project. School selection was based on two criteria: (1) existing relationships with the instructional coach, principals, and some teachers from earlier collaborations; (2) a predominantly BIPOC student population. The coach and principals shared information about CRRRAFT with all PreK teachers and educational assistants at both schools, and all who expressed interest joined the CRRRAFT team. The principal at DVP recruited four parent representatives based on her knowledge of parents’ interest and ability to represent other families. Initially, we tried similarly to recruit parents from LVAP, but language barriers prevented direct communication among university researchers and families. Instead, we relied on a non-profit that serves the Hispanic community to recruit three parent representatives based on parents’ interest in the program and ability to represent the families in the community. All recruited parents joined the CRRRAFT team.

DVP enrolls approximately 100 students in eight PreK classes, which include three- and four-year-old students. Specific racial/ethnic demographics were unavailable, but school collaborators confirmed that students predominantly identify as Black. DVP project members included four teachers (3 white women; 1 African American woman) and two educational assistants (both African American/Black women). Teachers had between 7-19 (median = 10) years of teaching experience, mostly at DVP, and three held advanced degrees (Master’s or Doctorate). Educational assistants had worked in the role for 26 and 28 years, and both had completed some college. Among the four parent representatives (3 Black women; 1 white woman), three had children currently enrolled at DVP; one had a grandchild previously enrolled.

LVAP enrolls approximately 200 students in grades PreK-1. Student racial/ethnic demographics were 34% Black, 59% Latinx/Hispanic, and 7% white, with over 50% of students classified as English Language Learners. Four classes of four-year-old students make up PreK. Two PreK teachers (1 white woman; 1 Black woman) from LVAP joined the project. Teachers had 11 and 8 years of teaching experience, respectively, mostly at LVAP, and one held a Master’s degree. The three LVAP parent representatives (all Latina/Hispanic women) had young children enrolled in other schools within the district.

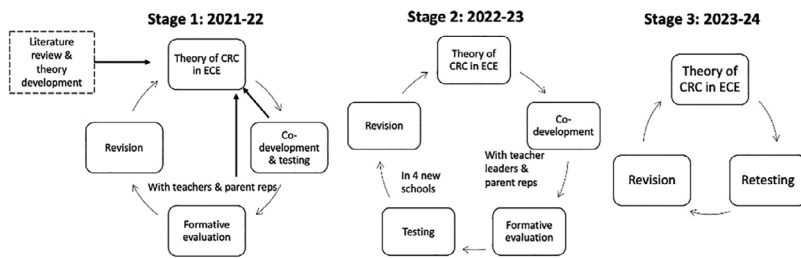


Fig. 1. Overall research design for project showing three DBR stages.

7. Research design, theories, and questions

Research design for the larger project included three DBR stages, each with iterative cycles of design, testing, and revision (Figure 1). Stage one involved the co-development and testing of the program based on a working theory of CRC in ECE, formative evaluation of program activities in classrooms and homes, and the ongoing revision of the program and theory. The second stage involved continued co-development and formative evaluation based on the evolving theory, as well as the testing of the program in new contexts and with new participants. Evaluation and testing informed additional revisions to the program and theory. Finally, the third stage will rely on a retesting of the program to support a final theory of CRC in ECE and necessary revisions to ensure the program's effectiveness.

The present study focused on the first DBR stage, specifically the co-development and pilot testing, formative evaluation, and revision of the theory and program from June to December 2021 (for more details see "Processes of DBR Stage 1"). Parents and teachers offered ongoing input to ensure short, responsive theory-practice feedback loops throughout Stage 1. The inclusion of both parents and teachers was important for two reasons: (1) limited guidance on translating theories of CRC in ECE into practice exists; and (2) successful implementation of STEM learning in ECE is based on collaboration among parents and teachers (Ata-Akturk & Demican, 2021; Dorie et al., 2014; Smetana et al., 2012), suggesting a similar need in computer science education.

The initial working theory of CRC in ECE (Harper et al., 2022) was informed by relevant literature and conceptual frameworks on culturally relevant teaching and computer science education in ECE, as outlined in the introduction. Design elements based on extant literature guided the initial co-development of program activities created and tested during meetings with teachers and parents. The research team used immediate feedback from teachers and parents to revise the working theory between meetings, which informed the design principles and co-development during future meetings. Teachers and parents also piloted, and formatively evaluated program activities in classrooms and homes between meetings, which informed the feedback they provided and the evaluations/revisions during/between future meetings. Thus, the program was co-developed through short iterative cycles, using formative evaluation to determine the number of iterations and cycles in DBR Stage 1 (Nieveen & Folmer, 2013).

Initially, the university team planned for teachers and parents to collaborate directly during meetings throughout the design process. Scheduling needs, however, necessitated separate collaborative planning meetings for the research team and teachers and the research team and parents, with the exception of two joint meetings (see "Materials Used as Data Sources"). Consequently, the theory of CRC in ECE was frequently revised (as indicated by the additional arrows in Figure 1). Researchers revised the working theory and design principles based on formative evaluations of collaborative efforts to translate the theory of CRC in ECE into practice during co-development and testing in meetings, classrooms and homes. Doing so allowed for both parent and teacher voice to inform future cycles of design, even if direct interaction of voices was not possible.

The concept of voice is salient for educational change (Hargreaves, 1996), specifically teacher and parent voice in PreK. Using a sociocultural approach to learning, which situates the learning processes in context and community, we sought to understand teachers' voices and parents' voices as a way to contextualize and compare the perspectives and roles of those most directly involved in the development and enactment of CRC for BIPOC preschoolers from multiple language communities. Learning is an ongoing process of developing an identity as someone who participates more centrally in a subject matter community (Lave & Wagner, 1991), in our case, as collaborators who facilitate CRC to promote CT in classrooms and/or homes. Therefore, Furman and Calabrese Barton's (2006) model for conceptualizing voice provided us with the opportunity to examine voice over time as a way to understand how teachers and parents negotiated evolving identities as the facilitators of preschoolers' CT development in culturally relevant ways (i.e., parent and teacher learning about CRC and CT). Accordingly, voice was operationalized as both perspective (i.e., what participants talked about, including the opinions, evaluations, possible solutions to problems, etc.) and participation (i.e., the choices participants made to actually take part in facilitating CRC and fostering CT) (Furman & Calabrese Barton, 2006). The following research questions were addressed:

- RQ1. How did teacher and parent voice inform the sense-making of CT and CRC (i.e., co-development of Culturally Relevant Robotics (CRR) Program and refinement of a theory for CRC in ECE)?
- RQ2. How did teacher and parent voice inform the testing and refinement of CT and CRC within the CRR Program across the school, home, and community spaces (i.e., enactment, evaluation, and revision of the CRC Program and theory for CRC in ECE)?

8. Processes of DBR stage 1

Co-development meetings began in June 2021, with teachers and parents immediately engaging in DBR. University and pre-existing school collaborators (instructional coach and principals) honored cultural diversity as an asset in our previous work. As such, we recognized the challenges inherent in bridging the different cultural worlds of researchers and practitioners that can collide in DBR collaborations (Coburn et al., 2013). Epstein and colleagues' (2019) framework for involvement was considered in how we centered parents' and teachers' perspectives in decision-making and collaboration with the schools and community. Parents joined the collaboration before teachers and were given support that enabled them to serve as representatives. Our approach removed the typical unidirectional form of communication between teachers and parents to validate the voice and expertise of parents from BIPOC and linguistically diverse groups, thus building culturally responsive collaborations (Constantino, 2015; Kayser et al., 2021). Accordingly, all meetings and conversations were designed to support ongoing dialogue to empower teachers and parents charged with educating young children (Alfred, 2002). Further, we sought to identify and address challenges around social, structural, and physical inequities (Wallerstein & Duran, 2010). Through these efforts, we also aimed to

support teachers in shifting their perspectives of parental and community engagement in program development and implementation to align with an asset-based approach. The prominence of both parent and teacher input into program co-development and decision-making provided opportunities for parents to develop awareness of their voices in school decisions and teachers to form awareness of parent perspectives as a factor in curricular decisions (Epstein et al., 2019).

To accommodate diverse needs of collaborators, teachers and parents often met as separate groups with university partners, and all collaborators had opportunities to reflect and communicate with university team members outside of scheduled meetings. Both teachers and parents participated in group meetings, but we also prioritized one-on-one conversations with parents. For a full schedule of meetings and their agendas, visit the CRAFT website (<http://craft.org>). The overall aim of the meetings was threefold.

8.1. Building inclusive culture

Meetings and conversations included trust-building activities and communication structures that facilitated inclusion of diverse perspectives and experiences. For example, the choice for teachers and parents to meet separately and to prioritize one-on-one conversations with parents was intentionally made based on parent input. In meetings, everyone may share opportunities to contribute, but team members with privilege on the basis of race, gender, class, or other sociocultural positions will more readily take up those opportunities. In seeking to ensure diverse team members provided input into project decisions, we sought to be especially purposeful about preventing exploitative emotional labor that can accompany equity-directed work for BIPOC individuals (Mercer-Mapstone et al., 2019).

8.2. Learning about CRC and CT in theory and practice

Given their different roles and expertise, teachers and parents needed varied types of experiences to learn about theory and research on CRC and CT and to make decisions about which ideas, practices, and materials to use in the CRR Program. Teachers read and discussed *Coding as a Playground* (Bers, 2019), and we explicitly introduced parents and teachers to the included powerful ideas from CT: (1) algorithms; (2) modularity; (3) control structures; (4) representation; (5) hardware and software; (6) design process; and (7) debugging. We facilitated plugged and unplugged activities using various tangible technologies and tools identified as appropriate for young children (e.g., Lee & Junoh, 2019; Macrides et al., 2022), and we provided time for teachers and parents to play freely with both unplugged (e.g., Robot Turtles board game; algorithm for brushing teeth) and digital (e.g., KIBO, Robot Mouse, Dash) tools and materials so that they might imagine new possibilities not yet identified in the research literature, especially in regards to CRC. We prompted teachers and parents to explicitly name and make sense of the powerful ideas in CT and from CRC that arose as they engaged with various tools and materials. Moreover, meetings provided a space for the university team and other teachers/parents to offer support as individual teachers and parents sought to pilot CRR Program activities in homes and classrooms to create culturally relevant opportunities for children to develop CT.

8.3. Co-developing the CRR program

Meetings served as the primary means for co-development of the CRR Program; all joint meetings with parents, school partners, and university partners were framed as co-planning meetings, in which both teachers and parents gave feedback on school-based and home-based program activities. The university research team used design principles agreed upon through co-development and formative evaluation from meetings to draft school- and home-based materials for two distinct curricular phases (i.e., units), piloted in Fall 2021 by teachers and

approximately 50 families across both schools (see our website for the current version of these phases; <http://craft.org>). Each phase highlights one powerful idea from CT across school and home, although opportunities to engage with multiple powerful ideas exist. Phase 1, which we named, “Order Matters,” emphasized algorithms. The school-based learning goal was: “Children will understand that using **steps** helps us to do tasks and solve problems in computer science, literature, and in daily life. *Sometimes the order of steps matter;*” and the home-based learning goal was: “Your child will understand that using **steps** helps us do tasks and solve problems in our daily lives. *Sometimes the order of steps matters.*” Phase 2, “Doing STEM,” emphasized the design process. The school- and home-based learning goal was: “Children/Your child will understand that using **the design process** helps us solve complex problems in our daily lives. *That means, STEM is for everyone!*”

School-based CRR Program materials provide a plan for one focal experience per unit, designed to be used by all teachers, that ensures an opportunity to engage with the highlighted powerful idea. Additionally, teachers choose from among a set of recommended activities, identified from research, existing curricula, and co-development, that build up to and reinforce the focal experience. Some recommended activities overlap across units. Home-based CRR Program materials include instructions and necessary tools for three separate activities per unit to create learning opportunities related to the goal. Parent representatives led the co-creation of two hour-long family nights at each school, in which approximately 50 preschool parents learned to engage in the activities from university, teacher, and parent facilitators.

9. Materials used as data sources

All materials for data analysis came from group meetings and one-on-one conversations from June–November 2021. Data sources included artifacts generated during, or for, meetings (e.g., comments written by teachers/parents); field notes recorded by university researchers during and/or after meetings or conversations; and transcripts of audio-video recordings. We intentionally chose not to generate audio-video recordings during in-person summer meetings to prioritize building trust among collaborators. To create a data set from a subsample of meetings and conversations, we reviewed agendas for all meetings and identified meetings in which parents and/or teachers were explicitly involved in DBR processes. We selected data sources that provided evidence of teachers and parents direct engagement in the co-creation of our working theory and the CRR Program, testing the program, and providing formative evaluations based on testing for the purpose of revising the program or theory (Table 1).

10. Data analysis

Following DBR methodology, CRR Program co-development utilized an iterative approach to creating, testing, revising, and refining each CRC learning activity. Accordingly, evaluation and data analysis was ongoing throughout the co-design and development processes. Ongoing data analyses leveraged deductive and inductive approaches to qualitative analysis (Azungah, 2018). Specifically, deductive analysis provided a means of exploring how the working theory of CRC in ECE mapped to practice; and inductive analysis served as a way to revise the working theory by allowing unexpected factors influencing practice to arise.

For the present study, Flowers and Rainwater began with an open-coding approach to inductively identify the content of talk with as little inference as possible for data sources from the September 27 meeting. They reviewed the preliminary codes and refined (e.g., reorganized, collapsed) them into parent and child categories. Definitions for each code were also added to the codebook. Then, they applied codes, individually and collaboratively, across all data sources. Codes were exhaustive, but not mutually exclusive, and were applied at the talk-turn level for transcripts and the topic level for field notes and other data sources. The entire authorship team met to discuss code application, addition of

Table 1
Summary of data sources by DBR process and participants.

DBR process	Participants	Type of Data and Source Summary of Data Content
Working theory co-development	Parents	Artifacts and Field Notes from <i>June 18 Group Parent Meeting</i> Written response to “What is culturally relevant?”; reflection after reading Kalthoff and Lim (2020) ; Co-created definitions of CT concepts from <i>How to Code a Sandcastle</i> (Funk, 2018)
	Teachers	Transcript of audio-video of <i>July 26 Advisory Board Meeting</i> Explanation of powerful ideas from CT to the advisory board and how CT ideas showed up within children’s communities during a community walk Transcript of audio-video of <i>November 17 Teacher Meeting</i> Discussion of powerful ideas from CT and how those ideas related to practices from Phase 1 and 2 testing; who can (e.g., teachers, parents) and how to support CT development and sense of belonging in computer science Transcript of audio-video & artifacts from online chat of <i>September 27 Co-Planning Meeting</i> Selection, creation, and discussion of definitions of CT
CRR Program co-development Testing	Parents & Teachers	Field Notes from <i>August 23 Co-planning Meeting</i> & Transcript of audio-recording of <i>September 27 Co-Planning Meeting</i> Co-creation of a final draft of at-home materials and preparation for upcoming family nights (Phase 1 & 2)
	Parents & Teachers	Transcript of audio-video of <i>November 8 Family Night at DVP</i> Hope (teacher) and Serena (parent) co-facilitated a session for parents on how to use the <i>Let’s Go Code</i> for Phase 2 at home
Formative evaluation based on testing	Parents	Field Notes from <i>June-July 2021 Group Parent Meetings</i> & from <i>Late July 2021 One-on-One Meetings with Parents</i> Feedback provided after parents tested tools/activities co-created during meetings with their own children
	Teachers	Transcript of audio-video & artifacts from online chat of <i>September 27 Teacher Meeting</i> Feedback after piloting school-based Phase 1

Table 2
Primary codes applied to data sources and their definitions.

Primary Code	Definition	Example Child Codes
Voice	Who was talking or participating in data	Parent; Teacher
Perspectives enacted through talk	Sense making of what computer science (education) and culturally relevant mean	
CRC	Sense making of what CT is (explicitly)	Powerful ideas (named or implied by description)
Feedback	Opinions or ideas for developing or refining the CRR Program and its enactment	Seeking feedback; Giving feedback
Perceptions	Opinions or views about others	Of self; Of children
Support	Supporting each other’s ideas or practices	Teacher to teacher
Participation enacted through choices		
Context	Where CRR Program, CT, CRC was engaged	Home, School, Family Night
Practices	Practices used to engage CRR Program, CT, CRC	Curriculum alignment; Differentiation
Tools	Materials or ideas used to engage CRR Program, CT, CRC	Cultural referents; Loose parts; Robots
Who	Who engaged in CRR Program, CT, CRC	Family, Child, Teacher

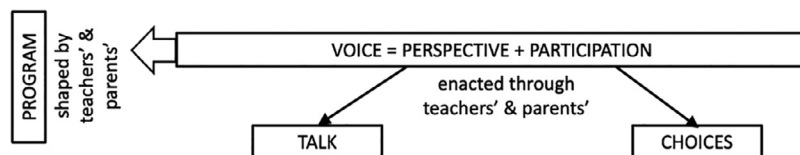


Fig. 2. Conceptual framework for the construct of voice ([Furman & Calabrese Barton, 2006](#)).

new codes, or refinement of existing codes and their definitions, arriving at consensus and the final codebook, after continually looking for confirming and disconfirming evidence. Using a code-to-theory model ([Saldaña, 2021](#)), we identified ten primary codes ([Table 2](#)) that led to the themes presented in the findings.

Next, we deductively applied our conceptual framework ([Harper et al., 2022](#)) to operationalize the construct of voice ([Figure 2](#)) to answer our research questions. We reviewed our codes, their definitions, and excerpts to relate them to the components of voice ([Table 2](#)). “Perspectives as enacted by talk” represent the group of codes in which participants made sense of CT or CRC; agreed with expressed ideas; shared perceptions of themselves or others; and gave or sought direct feedback on co-development and piloting of the CRR Program (RQ1). “Perspectives as enacted by choice” represent the group of codes in which participants described how they planned to pilot or piloted the CRR Program, including the setting, who participated, and the tools and practices used (RQ2). Using Dedoose Version 9.0.18, we viewed code occurrence tables to identify prominent themes and illustrative excerpts, and considered how the occurrence of codes changed across time (as an indication of learning; [Furman & Calabrese Barton, 2006](#)). We created data displays from code co-occurrence tables by voice and

perspective and by voice and participation ([Miles et al., 1994](#)) and reviewed excerpts to identify similarities and differences across teacher and parent voice. Finally, we compared the themes by teacher and parent voice and across time.

11. Findings

The CRRRAFT Partnership design principles were grounded on the notion that parents and teachers can collaborate directly to co-develop a CRC program for ECE. Yet, direct collaboration among teachers and parents was rarely logistically possible, and for this reason, the university research team served as a bridge between teacher and parent voice. Namely, researchers used explicit co-creation and formative evaluation done collaboratively with parents and teachers throughout short, frequent cycles of design, testing, and revision to refine the working theory of CRC for ECE, which shaped future design cycles. In other words, as teachers and parents sought to make sense of working theories of CRC and CT during the co-development process (RQ1), researchers drew on parent and teacher voice to revise the working theories, which in turn influenced later sense making and co-development. Similarly, as teachers and parents worked separately to test the program activities, formatively

evaluate them, and revise the program (RQ2), researchers drew on parent and teacher voice to refine design principles to translate working theories into practice, which in turn influenced later co-development and testing.

Findings suggest that cultural responsiveness and CT are interwoven and inseparable within the CRR Program and collaborative discourse. We separated findings related to these two broader concepts for clarity. Thus, we first share findings in which teacher and parent voice about cultural responsiveness was foregrounded. Then we turn to findings explicitly regarding voice about CT. Yet, these CT findings also highlighted more implicit CRC conceptions and practices, and we elaborate upon those as appropriate.

In each section, we first present findings from RQ1 related to how voice interacted to inform shared understanding of concepts (i.e., perspectives as enacted by talk). We then further elaborate on the interaction of voice to show findings for RQ2 from descriptions of program enactment across settings (i.e., participation as enacted by choices). These aspects of voice (i.e., talk and choices) were often coupled. We separate them to the extent possible for clarity, but we also note that selected excerpts may speak to both perspectives and participation.

12. Cultural responsiveness in computing education

Parents and teachers engaged in conversations about culture and culturally relevant education throughout the DBR cycles. On June 18, parents were asked to share their thoughts about the meaning of culture and culturally relevant. Several parents highlighted the importance of *traditions and customs* within *families and communities* as being important. Some also mentioned *identity*. Later in the same meeting, two parents expressed how the program should instill values of *community and school pride* as well as *kindness*. As such, parents' initial perspectives on CRC emphasized how the program should use CT to support development of cultural and community values and traditions. In other words, for parents the ultimate goal was cultural and community learning.

In contrast, teachers emphasized building upon culturally relevant experiences to make CT development more accessible for young children and their families. For teachers, the ultimate goal was CT learning. Teachers felt the materials and resources should be accessible to families to promote engagement and team members should use appropriate means of communication when sharing information. This included online access via the program website as well as messages sent within school communication apps, and parents agreed. During August 23 co-planning, Stacy (T⁴) expressed concern about how to support participation and engagement of emergent multilingual parents. The group of teacher, parent, and university collaborators decided that Harper would lead one group of parents in English and a parent would lead another group in Spanish.

Teachers' descriptions of experiences using culturally relevant materials and resources with children was the primary way their voice was represented regarding culturally relevant education. Teachers prioritized the use of instructional materials, particularly books and visuals, that are culturally and linguistically relevant. When sharing about a positive experience reading a book in Spanish to support the pilot, Stacy (T) [September 27] recognized how this could be challenging for other teachers:

For me personally, it was just because I can read in Spanish, but I don't know how it would be for a teacher who doesn't know how to read in Spanish, or is uncomfortable.

In the beginning of the collaboration, Wendy, Stacy, and Wanda (Ts) were upfront about their desire to grow as culturally relevant educators. On July 26, they sought individual feedback from advisory board mem-

bers about how to be more culturally responsive in their education of young children and efforts to partner with families. For example, Wendy (T) [July 26] asked:

I want to make sure that I am a culturally responsive teacher and, you know, I tried to make sure the books and the toys are diverse, but do you have any suggestions for other ways that I can make sure I'm doing all I can to achieve that?

Wanda (T) expressed a desire to be more "culturally responsive to parents and build that relationship with them so they feel comfortable talking to me about things that are going on at home" [July 26]. In addition to deepening their culturally relevant knowledge and practices and relationships with families, teachers were interested in potential opportunities to learn more about existing school-community collaborations. Stacy (T) shared [July 26]:

Many of our students at LAVP who are, I think about 65% of our population is—they speak Spanish as a second or third language, sometimes they speak different dialects from Guatemala as well. So what are some ways that [the non-profit] kind of integrates in the schools and helps support the students in our schools that we can work with?

Both parents and teachers expressed the importance of connecting the program experiences to familiar home activities and experiences. For example, on September 27, Wanda (T) described pointing out "other robots/computers (smart watch/Siri) children interact with in daily lives." These connections were the primary way in which parents and teachers chose to put CRC into practice, with strong connections to CT concepts. As such, we elaborate in more detail on this finding below in relation to specific CT powerful ideas that parents and teachers connected to familiar activities or experiences.

13. Computational thinking in CRC

During the September 27 co-planning meeting, parents, teachers, and university collaborators discussed how they personally defined CT. Next, they selected no more than five terms from a list of ten they considered most central to CT (see Table 3). A final exercise included selecting from one of five definitions that resonated with them most. Findings from analysis of their responses provide insight into how parents and teachers made sense of the broader concept of CT (as part of the CRC for ECE working theory), namely, through a shared emphasis on problem solving and algorithms.

Self-written definitions from teachers and parents both mentioned how CT is a particular type of thinking process that also includes an "order" or "series of steps" (i.e., algorithms). Wendy (T) and Stacy (T) also wrote that "problem solving" is a part of CT. Interestingly, Wanda (T) extended these ideas by defining CT also as "goal-oriented" and easily integrated into typical daily experiences children enjoy doing. She shared:

CT is a different language that places things in a logical order in order to accomplish a goal. For preschool age children you can equate this to something simple they enjoy doing, and the directions for doing so.

This idea of integrating CT concepts into authentic, familiar experiences was the primary approach both teachers and parents chose to enact the program in culturally responsive ways (as mentioned in the previous section). This perspective of integration influenced how they made choices in co-developing and testing the program.

In parallel to their self-written definitions, logical thinking and problem solving were selected as terms central to CT by both teachers and parents; however, algorithmic thinking, debugging, and problem decomposition were the most popular choices (Table 3). Even though coding was a primary focus of the program activities at both home and school, only two parents and one teacher selected the term. Likewise, teacher and parent selections of possible CT definitions (Table 3) indicated that both groups favored definitions that focused on "problem

⁴ We use "T" to indicate the participant is a teacher and "P" to indicate the participant is a parent.

Table 3
Parent and teacher selection of CT terms and definitions

Terms related to CT	Parents					Teachers			
	Desi	Grisel	Jaclynn	LaTonya	Serena	Hope	Stacy	Wanda	Wendy
Algorithmic thinking	*		*		*	*	*	*	*
Debugging or troubleshooting			*		*	*	*	*	*
Problem decomposition	*		*	*	*		*		
Problem solving			*	*	*		*		
Logical thinking			*	*	*	*	*		
Coding or programming	*		*			*			
Data representation	*			*					*
Modeling and simulation	*							*	
Pattern recognition				*					
Abstraction									
Possible definitions for CT									
“Computational thinking is a problem-solving process that includes (but is not limited to) formulating problems, analyzing and representation data, and algorithmic thinking” (ISTE as cited by Edwards & Cassidy, n.d.).		*			*	*	*	*	
“Computational thinking is the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer—human or machine—can effectively carry out” (Wing, 2014 as cited by Edwards & Cassidy, n.d.).	*								
“Computational thinking involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science.” (Wing, 2006 as cited by Edwards & Cassidy, n.d.).			*	*					

solving” or “solving problems” and algorithmic thinking. Additionally, the selections indicated a preference of both teachers and parents for prioritizing human action and agency (e.g., problem solving) over the role of computers in CT. The two definitions not chosen do not mention problem solving or solving problems. Namely, no one selected: “Computational thinking refers to the thought processes involved in expressing solutions as computational steps or algorithms that can be carried out by a computer,” (CSTA as cited by Edwards & Cassidy, n.d.) or “Computational thinking is what you do when you use a computer” (Edwards & Cassidy, n.d.).

Opportunities to define CT arose in other meetings and informal conversations. Through chronological analysis of code co-occurrences within data sources, we found conversations with parents and teachers across all data sources included their perspectives of algorithms and the process of debugging within algorithms. Additionally, the design process was documented in all data sources, but was more frequently discussed among the teachers. Because findings related to the design process did not address our question about how teacher and parent voice came together to inform theory and practice, we considered those findings beyond the scope of this paper. Thus, the following sections provide insights into the convergence and divergence of teacher and parent voice in relation to more specific CT concepts connected to algorithms, including debugging and control structures. We highlight how findings about CT related to CRC as appropriate.

13.1. Algorithms

Across meetings, algorithms were mentioned in similar amounts among parents and teachers, and these conversations mostly centered on how to effectively explain and teach this concept to children as well as experiences doing so. Both parents and teachers were able to incorporate the idea of algorithms through sequencing and routines. Parents described the importance of being increasingly specific over time when teaching algorithms to children. They also felt simplifying and comparing steps helped children understand the concepts. One parent mentioned stating to children, “Let’s think of the steps,” is easier for them to understand than “sequencing.” When asked how they would explain important concepts, namely program and sequence, to support children’s development of algorithmic thinking, they described a program as a plan or situation that includes “instructions a computer can understand.” In these discussions, parents perceived sequence to be an order or series of

steps [June 18]. Parents also shared how specific life experiences can be used in authentic ways to teach algorithms that differ depending on the task. For example, the steps involved in selecting eggs at the grocery store, making a sandwich, and hand-washing were all discussed and used as opportunities to teach algorithms in culturally relevant ways.

Teachers shared similar perspectives about using familiar routines as algorithmic learning opportunities, but emphasized school-based routines rather than home-based activities. Five teachers, including an educational assistant, mentioned making use of classroom routines, transitions, and activities that already involved sequencing to explicitly teach algorithms. These learning moments included teaching sequencing within morning and bathroom routines. Stacy (T) also connected algorithms to a child-led activity where children created their own daily classroom schedule by sequencing part of their day on a blank schedule [September 27]:

Did this with the daily schedule and picture cards—some differentiation to include parts of the day for some children and some children worked with a blank schedule and fully sequenced the parts of the day.

Parents expressed their enactment of algorithms most often by sharing how they enacted at-home activities. Data from August 23 showed that they described practices related to algorithms in ways that overlapped with and interacted with teacher themes. Latonya (P) shared how she enacted sequencing and debugging at home. While making a bologna sandwich she asked her granddaughter to describe the steps to enact the CT powerful idea of algorithms. Her granddaughter shared, “Get the bread, put on the bologna,” and “Eat it.” Latonya described how she enacted debugging through natural integration next. She laughed when sharing how she asked her granddaughter if she would take off the red ring around the bologna or eat that. The granddaughter said, “Granny, you’re silly,” and then took the red ring off the bologna without describing it as a step in her algorithm.

Parents and teachers also described using the robotics materials in the pilot to introduce and reinforce concepts related to algorithms, such as through step-by-step instructions on how to code the robot mouse movements (e.g., forward, backward, turn). At the November 8 family night, Hope (T) shared how this could be done with children using the *Let’s Go Code* materials:

So the idea is that robots don’t know what to do unless you tell them what to do... So, you can tell your child a story. “The robot is broken. We’ve

got to get to it and we have to get him two springs. How are we going to get there?"

13.2. Debugging

Debugging was discussed by parents and teachers in relation to algorithms, but was prioritized slightly more in teachers' conversations. Both teachers and parents emphasized the importance of identifying activities that interested children in order to support children's willingness to struggle with debugging issues. On June 18, parents defined debugging as fixing, redoing, or figuring out what is wrong. Similarly, across meetings, teachers mentioned debugging as a process for turning problems or "mistakes" made in algorithms into learning opportunities. At the family night, Hope (T) shared with parents how she perceived debugging in relation to planning out the entire program to pick up the springs and take them to the robot:

And when they [children] test it, sometimes it's even good if they encounter a problem or they did something wrong because that's a teaching moment. Right? We can say, "Oops, what happened? What should we fix? And then let's fix it." [Hope]

In computer science, we call that debugging. [Harper]

Serena (P) further elaborated by providing an example from a culturally relevant, place-based activity (see Harper et al., 2021) parents and Harper co-developed together:

We had [the robot mouse] go to the store and pick up certain items like fruit, cheese and ice. But as parents, you know, that you have to get one of those things home before they expire....If this is starting at your house...which route are you going to go so that you get that thing [that expires] last and get it home so it doesn't spoil? It's things like that, debugging your methods. How can I do that in these steps and make it efficient?

Moreover, our data included instances of families working through debugging with their children, without directly stating "debugging." Latonya's (P) example of her granddaughter removing the red bologna ring and laughing was an implicit example of debugging. Families shared high levels of child-cognitive debugging when engaging in testing the at-home activity in which they would "Code-a-parent" how to walk, like a robot (similar to *Let's Go Code!*). Families shared their children's resilience and frustrations with debugging. Two Hispanic mothers shared their support of their children's development by keeping it fun when their child grew intolerant of "fixing what was wrong."

Teachers also expressed the importance of opportunities for children to freely explore with the robots, while keeping it fun, so they could navigate problems using their own strategies. In the August 23 co-planning meeting, Rhonda (T) noted how she felt it was important for children in her class to engage in robot mouse activities in ways that helped them learn through experience and not by prioritizing accuracy. On November 17, Wendy (T) noted how teachers' responses to the bugs directly impacted children's perceptions of them:

And you just have to really be positive and be excited for their ideas and be excited for everything they try, even if it just totally goes awry. Just be excited that they came up with something. They're trying and they're going to try again. So, you know, and always encouraging that. "Well, let's build it again, let's try it again, well how else can we do it?" So that they don't see their mistakes, the quote unquote "bugs" as a negative so that they can see it in a more positive light themselves, so they don't get frustrated.

Similarly to teachers, parents discussed how debugging opportunities during activities and games, or within typical daily experiences, are ways to "normalize" mistakes. Moreover, on June 18, a conversation about debugging moved into considerations about culture. One parent shared how, in some cultures, mistakes are viewed as negative so we

should take that into consideration when developing program activities that are culturally responsive.

In addition to valuing mistakes, both parents and teachers related debugging to problem solving more generally. In the above excerpt from the family night, for example, Serena (P) implied that debugging is related to finding the best way to solve the problem at hand. Similarly, Stacy (T) mentioned a desire to be more intentional in her use of the term "debugging," which she viewed as solving problems or finding solutions [November 17]:

We're doing a lot of the [school curriculum] problem solving, social problems and solutions suitcase. So I was like, I'm going to use that word "debugging" because we keep saying like we are solving problems or we are finding solutions, so I'm like we can use that debugging, we are debugging social problems too.

Teachers created collaborative learning environments for children to debug while interacting together with the robots, in ways that parents could not necessarily do. Wendy (T) noted how it was interesting to observe one of the children in her class teach peers how to program a mouse to go the intended way after noticing they were programming it to go in undesired directions [August 23]. In the summer, teachers were able to learn from one another in similar ways as they built robots using loose parts and the design process. For example, Wanda (T) reflected on an experience where she sought ideas from her colleague when she encountered a problem [July 26]:

I am right on top of one of the seven powerful ideas which is debugging because the first thing that happened is I went to tape two materials together and the tape would not stick. So I tried rolling the tape differently and that did not work, so I looked at my neighbor and they were using duct tape, so I switched the tape and that started working better.

13.3. Control structures

Control structures were discussed in comparable amounts among parents and teachers, but not consistently across the data sources, and both teachers and parents were able to build on children's prior experiences and knowledge bases to connect to the idea of control structures. Conversations about control structures occurred in the summer and then reappeared in late fall during the family night and when teachers were encouraged to revisit the powerful ideas in CT from the working theory. Parents and teachers noted that "loop" and "if-then-else" structures were difficult concepts to explain to children and for them to understand. Attempts to define this concept were often vague. For example, Wanda (T) described control structures as involving patterns and repetition as well as cause and effect [July 26].

On June 18, parents made sense of "loop" and "if-then-else" structures in relation to a children's book. They perceived the concept of a loop to be misleading for children since it does not look visually like a circle. Parents initially described "if-then-else" through culturally relevant examples, such as: "If there is broccoli on your plate then you eat it, else you don't leave the table." After having conversations with their children, parents realized if-then-else was a difficult concept to explain and describe to children. This prompted the group to create a more general shared definition at a later meeting: "If [Rule], then [what you do when the rule is followed], else [what you do when the rule isn't followed]." Further, on August 23, Gabby (P) shared how she chose to guide a CT talk with her child at the grocery store, choosing to talk about the way they purchase eggs and select fruit on sale as an "if-then-else" loop. Gabby called this sequencing and implied control structures within sequencing in culturally responsive ways. We found this to be similar to and overlapping with how teachers chose to enact algorithms and embedded control structures in their classrooms.

For example, teachers' descriptions of practices demonstrated that they built on children's experiences with cause-and-effect relationships to introduce the concept of control structures. For example, on July 26,

Wanda (T) described a learning experience that involved building a tall tower with small red cups (using the design process). She shared how children began to notice a pattern that each small red cup base had the same size that supported the tower; however, when the teacher put a larger object on top of the tower, it collapsed. Children were able to connect the observation to the idea of cause and effect, which Wanda considered a control structure (i.e., if-then). On November 17, teachers' revisited the powerful ideas from CT with members of the university team. Stacy (T) mentioned how this process helped her understand some of the more complex concepts, such as control structures:

It's helpful to hear you [Harper] break it down because I never really understood that powerful idea, but now that you say it like that I'm like oh okay, so they are doing that and using them in the classroom. It's helpful to have an example.

14. Discussion

Findings from both teacher and parent perspectives and participation informed the ongoing refinement of a working theory for CRC for ECE throughout the DBR Stage 1. In this section, we discuss how the foregrounding of parent and teacher voice raised a need to revisit and reconsider what is known from existing theory and research. Specifically, we provide insights into how this analysis informed our efforts to bring together theories of CT in ECE (Bers et al., 2019; Bers & Sullivan, 2019; Lavigne et al., 2020) and CRC (Scott et al., 2015), and to translate theory into practice.

15. CT in ECE with BIPOC children from multiple language communities

Findings from both teacher and parent perspectives and participation in the co-conceptualization of CT indicate that both groups engaged and facilitated key concepts such as algorithms, debugging, and control structures in ways similarly found in the existing literature from early childhood computer science education (e.g., Bers et al., 2019; Lavigne et al., 2020). Although our analysis broke CT into distinct concepts, parents and teachers made sense of these ideas in interconnected ways, mostly through connections to sequencing of familiar home and school routines. Such an unplugged approach to supporting children's CT is common in ECE (e.g., Lee & Jonah, 2019), but our findings suggested that this approach was also key to teachers' and parents' own understanding of CT as it showed up throughout evidence of the CT perspective and participation.

Although parents and teachers conceptualized CT similarly, important differences arose in what they emphasized and the choices they made when putting ideas into practice with young children. These differences are important because the extant literature on CT in ECE includes only school-based or informal learning contexts outside of children's homes (Macrides et al., 2022). CT learning by young children in the informal context of the home has yet to be considered, and thus considering parent voice alongside teacher voice highlighted potential areas for future ECE research on CT generally and CRC specifically.

As mentioned, teachers and parents similarly emphasized conveying powerful ideas from CT (i.e., algorithmic thinking, debugging, patterns; Bers & Sullivan, 2019) through familiar routines. Findings suggest, however, that teachers chose to focus mostly on school-based routines while parents focused on home-based routines. This choice had implications for how opportunities for self-expression, increasing complexity, and debugging (Bers & Sullivan, 2019) arose. In conceptualizing CT, teachers emphasized algorithmic thinking more than parents did; meanwhile parents emphasized problem solving more than teachers did (Table 3). This difference showed up also in the way teachers talked about sequencing familiar routines as "directions" [Wanda] or "tell[ing robots] what to do" [Hope]. In other words, teachers' perspectives and participation in CT through familiar routines suggested a procedural, rule-following

emphasis. In contrast, parents described opportunities for more self-expression (Bers & Sullivan, 2019) when "naming the steps," such as being silly when making a sandwich [Latonya] or making choices about efficiency [Serena] or grocery purchases [Gabby]. Instead, evidence of promoting self-expression was found in teachers' choices related to emphasizing debugging in other CT activities, such as during free play with the robot mouse [Rhonda; Wendy] and in using materials to create "robots" [Wanda].

Our analysis also showed a difference in teachers' and parents' choices about how to differentiate activities for novice engagement and increasingly more complex tasks (Bers & Sullivan, 2019). Teachers tended to focus on differentiation for novice engagement. For example, Stacey described having different versions of the daily schedule for connecting school-based routines and algorithms in a way that suggested students would use the schedule accessible to them (without an opportunity to engage with the more complex versions). In contrast, parents considered novice engagement in how they described concepts to children, but also emphasized the importance of increasing the specificity of "naming the steps" of home-based routines over time (i.e., increasingly more complex tasks).

These findings point to a need for future research to consider the common practice of supporting coding through unplugged activities related to familiar home and school routines (Lee & Jonah, 2019). Specifically, what might the field learn from a closer examination of these unplugged activities focused on familiar routines in the home setting versus in the classroom-setting? Such explorations have the potential to reveal possible limitations to the unplugged approach of connecting familiar routines and coding in school contexts. Because children's learning is shaped across social contexts (Goodnow et al., 1995; Goodnow, 2010) and through guided participation in cultural activities, including the cultural practices of school (Rogoff, 2003), a better understanding of home-based CT in ECE is necessary to realize children's self-expression and to position all children as capable of complex tasks (Bers & Sullivan, 2019; Newton et al., 2015).

16. CRC in ECE

Other tensions that arose between teachers' perspectives and parents' perspectives suggest important implications for the development of CRC, specifically, in early childhood. One such tension arose in how teachers and parents positioned the purpose of integrating culturally responsiveness with computer science education. Overall, both groups agreed that CRC should reaffirm children's cultural and home-based practices and values, but they disagreed on to what end. Namely, teachers prioritized CRC for the purpose of making CT more accessible to young BIPOC children and children from multiple language communities, two groups historically ignored in computer science education. In other words, the ultimate goal is for those who have not previously had CT learning opportunities to gain access to such opportunities. In contrast, parents tended to emphasize the importance of using CT, as a new educational content area, to reinforce cultural and home-based values and practices. In other words, the ultimate goal is to further support culturally relevant ways of knowing and using CT.

Both of these goals are an important part of how CRC is currently conceptualized. Integrating students' cultural and home-based practices within the school curriculum is a hallmark of culturally responsiveness (Ladsen-Billings, 2009; Gay 2018). Research on CRC (e.g., Newton et al., 2020) suggests that drawing from students' cultural experiences supports students' CT and possibly increases BIPOC students' self-efficacy and interest in technology. Prior studies have noted the importance of using students' culture as a strength-based asset to build knowledge and skills in CT (Leonard et al., 2016, 2018) because doing so positions all students as capable of digital innovation (Scott et al., 2015). Prioritizing cultural connections as a vehicle for CT learning (as teachers did), however, fails to realize the full potential of CRC. Parents' emphasis on using CT as a vehicle for learning cultural practices and values better aligns

with other principles of CRC that stretch the boundaries of what computer science can do (e.g., help us learn cultural practices and values; help critique stereotypes that position BIPOC children as not belonging) by challenging who creates and to what ends (Scott et al., 2015). Examples of realizing these principles in practice in extant literature include instances of older students developing critical consciousness as they use technology to address social and community problems important to them (Madkins et al., 2020).

These different priorities within CRC are especially crucial in light of the fact that some powerful ideas from CT inherently make computer science culturally irrelevant for some groups of students (e.g., linear sequencing is culturally irrelevant to Indigenous narrative approaches; Eglash et al., 2020). For example, in the present study parents emphasized how mistakes are viewed negatively by some cultural groups, placing debugging in conflict with some cultural and home-based practices and values. When teachers exclusively emphasize connecting CT concepts to familiar activities or experiences from home or school as a way to teach CT (as was largely the case in the present study and in existing literature; e.g., Campbell & Walsh, 2017; Heikkilä & Mannila, 2018; Lee & Junoh, 2019; Lee, 2020), they may overlook how some CT concepts themselves are at odds with culturally relevant ways of knowing. In other words, prioritizing access to CT learning opportunities may inadvertently conflict with the parents' priority and CRC principles that foreground home-based and cultural values and ways of knowing.

Differences in teachers' and parents' priorities for CRC in the current study point to the need to identify and make explicit all principles of CRC in ECE. Specifically, future DBR might explore how using CT as a vehicle for reinforcing cultural practices and values across both home and school contexts relates to developmentally-appropriate critical consciousness and connections to social and community issues, such as has been done in early childhood mathematics education (e.g., Ward, 2017). Alternatively, future studies might focus on identifying cultural heritage artifacts that introduce powerful ideas from CT to young children in developmentally appropriate ways. Examples using cornrow hairstyles in the African diaspora (Eglash et al., 2013) and iterative patterns in weaving (Lachney, 2017) in middle and high school computer science education exist, but models for early childhood computer science education are yet to be developed.

Conclusion

This study showed that connecting powerful ideas from CT to familiar activities and experiences from home and school served as a powerful entry point to participate in CRC for both teachers and parents. Thus this study reinforces that children (and teachers and parents) learn best when learning is connected to their daily routines and lived experiences (Lee & Junoh, 2019). Some examples of familiar activities and experiences identified in the present study may seem generic, rather than culturally specific, to some readers. Parents' voice, however, brought attention to how widespread experiences (e.g., making a sandwich) vary across cultural and family contexts. For example, in the present study, knowing that bologna sandwiches use bologna slices surrounded by a red ring requires culturally specific knowledge. Further, cultural ways of knowing became especially evident when parents made sense of the "if-then-else" structure. Their example (i.e., "If there is broccoli on your plate then you eat it, else you don't leave the table.") was created in direct contrast to an idea that Harper shared from an earlier teacher meeting: "If you eat your broccoli, then you get a cookie." Parents emphasized that such a practice was not common among Black mothers.

A cultural model in education bridges children's familiar experiences and skills with school content (Darling-Hammond et al., 2020; Lee, 2007), which requires teachers to know and understand children's CT practices and prior skills with CT concepts. Parent collaboration brought this intimate knowledge of cultural practices and values as well as community experiences to foster CT and a sense of belonging in computer science. Moreover, their involvement ensured advocacy

for other parents. Models for incorporating teacher and parent input on the design, development and implementation of curricular programs exist. For example, engineering education programs in ECE have successfully established parent-teacher collaboration to support children's learning of engineering education (e.g., Ata-Akturk & Demican, 2021; Dorie et al. 2014; Moomaw & Davis, 2010; Semetana et al., 2012); however, there is a paucity of examples in computer science ECE that include parents, teachers, and children experiencing and learning CT concepts together in culturally relevant ways. In order to support BIPOC children's learning of computer science education, parents and teachers need to understand computer science, CT concepts, and culturally relevant uses of practices within computing. The present study provides a possible model for fostering parent-teacher collaboration towards the goal of supporting CRC in ECE and raises questions for the field to consider as we bring principles of CRC into the homes and classrooms of young children. As a final caveat, however, we note that the DBR model alone is insufficient for building the trusting and mutually beneficial relationships necessary to ensure diverse team members provide input into project decisions across all stages. Additional frameworks that position diversity as an asset and explicitly interrogate power are necessary to build truly inclusive collaborations.

Declaration of Competing Interest

We have no conflicts of interest to disclose.

CRedit authorship contribution statement

Frances K. Harper: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Lori A. Caudle:** Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Charles E. Flowers Jr.:** Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing. **Tabatha Rainwater:** Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing. **Margaret F. Quinn:** Conceptualization, Methodology, Investigation, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Data availability

The authors do not have permission to share data.

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