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Asset-Based Computational Thinking in Early Childhood Classrooms: Centering Students' Expertise in a Community of Learners

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Abstract
Computational thinking CT is central to computer science, yet there is a gap in the literature on the best ways to implement CT in early childhood classrooms. The purpose of this qualitative study was to explore how early childhood teachers enacted asset-based pedagogies while implementing CT in their classrooms. We followed a group of 28 early childhood educators who began with a summer institute and then participated in multiple professional learning activities over one year. Examining a subset of the larger group, findings illustrate how teachers intentionally created learning communities that empowered students and utilized their expertise to guide CT learning in their classrooms. Teachers recognized that asset-based approaches to CT instruction empowered not just their students but also themselves. By using asset-based CT pedagogies, early childhood teachers can better support students from marginalized communities, reducing achievement gaps and inequities in digital learning.

Keywords Computational thinking · Early childhood · Teacher learning · Asset-based pedagogies

Introduction

Computational thinking (CT) is central to computer science (CS), yet there is a gap in the literature on how CT emerges and develops in early childhood, especially for children from historically marginalized communities. Lack of access to computational materials and effective instruction can create inequities that have lasting effects on young children (Chaudry et al., 2021). To alleviate the pervasiveness of such inequities and remedy the "pedagogical dominance of Whiteness" (Baines et al., 2018, p. 10), asset-based pedagogies as part of culturally responsive computer science approaches are needed (Madkins et al., 2019). And yet, understanding how teachers provide asset-based opportunities for computational thinking in early childhood classrooms remains largely unknown (Harper et al., 2023). In this paper, we share findings from a qualitative study that explored the ways in which early childhood teachers (ECT) learned and implemented computational thinking in their classrooms. During a year of classroom observations, interviews, and teacher meetups, we wondered if early childhood teachers would introduce CT in a way that honored students' "voice, agency, and self-determination" in additive ways that "engage students as emerging experts, support peer-to-peer teaching and learning, and encourage ongoing feedback" (Kapor Center, 2021, p. 2–3).

As a component of culturally responsive pedagogy (Ladson-Billings, 1995), asset-based pedagogies lead with students' strengths, on the belief that students possess unique life experiences and abilities which can be leveraged to foster effective and meaningful learning experiences (Goodwin, 2005). Teachers who implement asset-based approaches resist deficit beliefs that focus on what students lack, or what they cannot do. Instead, they place value on students' strengths, insights, languages, and cultural practices. Additionally, asset-based pedagogies critique injustices, oppression, and other social-political issues (Flint & Jaggers, 2021).

In this study, we explored asset-based approaches to computational thinking in elementary classrooms addressing the following question: After participating in a professional learning program focused on computational thinking, how do early childhood teachers enact asset-based pedagogies while implementing computational thinking in their classrooms?

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Literature Review

Computational Thinking in Early Childhood Education

The concept of CT—what it is; how it works; why it matters—is evolving. Wing (2006) initially positioned computational thinking as human-centered cognitive and dispositional problem-solving skills that did not include computational machines. Wing's (2017) reformulation acknowledged the role of computational machines by provisionally including them—"human or machine" (p. 8)—in her definition. The emphasis on computational thinking as a way of *human* thinking entangled with and amplified by the capacities of the computer is explicit in the K-12 CS Framework (2016): Computational thinking is "the thought processes involved in expressing solutions as computational steps or algorithms that can be carried out by a computer" (p. 68); and, "Computational thinking requires understanding the capabilities of computers, formulating problems to be addressed by a computer, and designing algorithms that a computer can execute" (pp. 68–9). From this perspective, the Digital Promise Foundation (2017) argues that learning to think computationally is crucial "because computational technologies are transforming so many dimensions of modern work and life, … [and because] computational thinking is a critical part of what is important to know and know how to do in a computational world" (p. 4). Further, Digital Promise argues that because computational thinking is so broadly relevant to human life, it should be taught across all K-12 content areas (p. 5). CT has become an important concept in early childhood classrooms and many computer science researchers suggest that when implemented early, computational thinking has the potential to shape young children's thinking, knowing and expressing and ultimately provide opportunities for them to grow into effective and innovative problem solvers (Lavigne et al., 2020; Rehmat et al., 2020; Tang et al., 2020).

The professional learning program used in this study leaned on two CT learning frameworks derived from early childhood computer science research: Computational Fluencies (Brennan & Resnick, 2012; Resnick, 2017) and Powerful Ideas (Bers, 2021). According to these frameworks, computational thinking is a process of thinking and learning that requires deep understanding of the connectedness of computational thinking concepts, practices, and perspectives and views "computing as more than something to consume; computation is something to design and use for self-expression" (Resnick, 2017, p. 10). To prioritize CT concepts and habits of mind that are developmentally appropriate for early childhood computer science education, Bers (2021) created the Powerful Ideas framework. Powerful Ideas are related to early childhood concepts and skills already present in children's in and out of school experiences. Similarly, she aligns the Powerful Ideas with a framework called Positive Technical Development to highlight the personal growth that occurs as children learn to communicate with new and traditional computational tools. Bers (2021) stresses that CT does not demand positive development, but instead nurtures a learning environment that supports positive development (p. 132). See Fig. 1 computational thinking conceptual framework.

Asset-based Pedagogical Approaches

Asset-based approaches to teaching computational thinking to young children are a part of culturally responsive pedagogies (Ladson-Billings, 1995) that incorporate students' insights, languages, and cultural practices into instruction to promote equity and agency in knowledge building (McCann & Yadav, 2023). Emphasizing the value of each student's contribution, asset-based instruction fosters classroom community through reciprocal, inquiry-based learning (Flint & Jaggers, 2021; Goodwin, 2005). Principles such as valuing everyone's input, collaboration, and shared responsibility through peer-to peer teaching and learning are embedded in instructional practices encouraging mutual support and collective ownership of knowledge (Scott et al., 2015). Examples of such practices include nurturing a safe learning community and the use of inclusive language in the classroom, such as "we" "us" and "our," anchoring instruction in students' interests, and encouraging students to share their expertise with peers. Flint and Jaggers (2021) argue that asset-based approaches acknowledge multiple ways of knowing by centering students' expertise in the learning environment, thus engendering a sense of belonging, agency, and well-being among learners and teachers alike.

In recent years, intersections between digital learning and asset-based pedagogies have gained attention for their potential to enrich teaching methodologies and promote inclusivity (Harper et al., 2023; Jocius et al., 2023; Luo et al., 2023; McCann & Yadav, 2023). This surge in interest around asset-based approaches in computer science education aligns with Grover's (2021) articulation of an urgent need to explore culturally relevant pedagogies. Grover (2021) argues that the field of computer science education lacks a robust understanding of the affordances of such approaches and that deploying them in classrooms might point the way to broader participation across divergent populations and grade levels. Grover's (2021) argument underscores earlier calls to recognize and incorporate learners' cultures, languages, and experiences as assets for authentically engaging with computing (e.g., Madkins et al., 2019; Scott et al., 2015).

Computational Fluencies (Brennan & Resnick, 2012; Resnick, 2017)	**Powerful Ideas/Positive Technical Development** (Bers, 2021, 2012)
Computational Concepts: Operators, data, events, sequences, conditionals	**Algorithms**: Series of ordered steps to solve a problem- sequencing/order **Modularity**: Breaking tasks into manageable units- writing instructions/grouping **Control Structures**: Order/sequence of instructions in an algorithm-patterns/cause and effect **Representation**: Letters, sounds, numbers, certain behaviors as meaningful symbols-models **Hardware/Software**: Relationship between physical and digital tools- cars/computers
Computational Practices: Testing, debugging, reusing, remixing, abstracting, iterating	**Design Process**: Iterative creation of programs/artifacts involving several steps-editing/revision **Debugging**: Systematic process of analyzing and evaluating using testing, logical thinking - problems solving/perseverance
Computational Perspectives: Expressing, connecting, questioning	**Collaboration** **Communication** **Community Building** **Content Creation** **Creativity** **Choice of Conduct**

Fig. 1 Computational thinking conceptual framework

Broadly speaking, attention to culturally responsive computer science education aligns with asset-based approaches. For instance, Scott et al. (2015) explicitly describe culturally responsive teaching as a "stark contrast to deficit models of thinking…which fault students' personhood, communities, backgrounds, and families"—attributes that culturally relevant teaching values "as assets on which learning can occur" (p. 414). Similarly, Madkins et al. (2019) highlights the importance of aligning computer science curriculum and instruction with young students' cultural and family experiences, because these asset-based strategies allow students to connect computer science to their daily lives.

Further supporting the shift towards asset-based pedagogies, McCormick and Hall's (2022) scoping review highlights a gap in early childhood computer science education research, particularly the need to differentiate between "task-oriented experiences" and "opportunities for free, or explorative play with computer thinking tools" (p. 3803). From an asset-based perspective, open-ended approaches empower learners to engage with computational concepts through self-expression, creativity, and connection with others, thus aligning with Flint and colleagues' (2021) call to value students' voices and choices in their learning processes.

Methodology

In this paper we drew on qualitative data from *Exploring Early Childhood Teachers' Abilities to Identify Computational Thinking Precursors to Strengthen Computer Science in Classrooms* (EPK-2), a yearlong professional development program centered on computational thinking and was performed in line with the principles of the

Declaration of Helsinki. Approval was granted by the Ethics Committee of University B (May 2020/7239). The yearlong program began with a summer computing institute that introduced participants to computational thinking in the context of PK-2 classroom teaching. Over the course of the school year, participants were observed in their classrooms, interviewed about their teaching, and invited to teacher meetups, coaching sessions, and a teacher conference to share ideas about and examples of implementing computational thinking in their classrooms. Informed consent was obtained from all individual participants included in the study.

Summer Computing Institute

The yearlong program began with a two-week summer computing institute that positioned computational thinking as expressive meaning making. Over ten days, we implemented computational making activities with a material inquiry approach (Justice, 2019). Material inquiry – a materiality-centered art education framework (e.g., Hafeli, 2015; Pacini-Ketchabaw et al., 2017) is a way of teaching where learners explore tools and materials for their unique affordances and characteristics and work with multimodalities to inform meaning making. Material inquiry draws from a learning principle articulated by Hafeli (2015) as *purposeful play*, and from sociomaterialism's commitment to multimodal sensemaking as an entangled, materiality-infused literacy (Hawley, 2022). Material inquiry blends computational and non-computational materials, such as microcontrollers, circuits, cardboard, glue guns, and software platforms like ScratchJr. Such blending allows for experimentation with different modes of expression and meaning making, fostering a natural and collaborative understanding of computational thinking.

At the institute, participants worked with computational tools and materials like Scratch, ScratchJr., and various robotics platforms, to compose stories, respond to a variety of children's literature, and make art for themselves and each other. While doing so they explored the affordances of computer programming and robotics for meaning making and expression, and reflected on why introducing computing in their classrooms might be worthwhile. Readings, videos, and group discussions about CS education principles (Bers, 2021; Brennan & Resnick, 2012) and the effects of computing in the world were an important aspect of the institute. To leverage the serendipitous effects that materials can contribute to learning, and to help our participants through their first challenging encounters with these unfamiliar tools, we designed the curriculum as a series of purposeful play and inquiry activities, featuring:

- Art, science, and storytelling with screen-based platforms (Scratch, ScratchJr.) and screen-free robotics (KIBO, Ozobot, Edison).
- Low-floor challenges ("Make the sprite move!" "Make the robot dance!") with high-ceiling potential ("How did your family come to (city name)?").
- Hands-on storymaking (Compton & Thompson, 2018) with computational tools and materials.
- Reading circles and reflective writing on the effect of computing on individual and community identities.
- Field trips to early childhood learning centers and cultural centers/museums.
- Individual and grade-level action plans for leveraging CT to support and extend what participants already teach.

Participants were invited to engage with a diverse set of computing challenges emphasizing process over product. For example, when learning *to do* something, like programming a robot to tell a story, we asked participants to focus on what they were learning and to document their journey with diagrams, sketches, and notes. We emphasized collaborative participation with reflective show-and-share sessions for both individual and small group learning activities.

As an intentional design feature of the institute, during week one we encouraged participants to experience the activities as learners and to deeply reflect on what and how they were taking in and making sense of CT. During week two, teachers focused on how their learning could influence how they implemented CT in their classrooms, and what instructional practices and learning standards they would align CT with. This design feature builds on research that suggests teachers who are positioned as learners are more likely to reflect on their teaching practices and implement enacted practices in their classrooms (Postholm, 2011). Similarly, throughout the institute we situated ourselves as learners alongside the participants, as guides inviting exploration rather than as experts with ready answers or step-by-step instructions for each challenge.

Yearlong Support

In addition to the summer computational institute, participants engaged in year-long professional learning that included two to three lesson observations, post observation interviews, group meet ups, individual and group coaching, and a teacher conference. In lesson observations, participants integrated CT in their regular curriculum. Lessons were videotaped and teachers participated in video recall interviews (Cherrington & Loveridge, 2014) where they reflected on their teaching and students' learning. They attended four group meet ups with fellow participants, where they discussed instructional decisions, student artifacts, and opportunities/barriers to implementing CT in their classrooms.

Twice during the year, they attended online coaching meetings facilitated by Assaf and Justice. Coaching sessions allowed us to provide individual feedback and explicit instructional suggestions to scaffold learning. The teacher conference took place at the end of year three. Participants presented integrated CT lessons to other teachers, administrators, and teacher educators from the local university. The goal of the teaching conference was to provide an authentic space for teachers to articulate and demonstrate what they learned and how they integrated CT in their classrooms.

Our approach drew from research on effective elements of professional development (Darling-Hammond, 2020) and generative change theory (Assaf et al., 2016; Ball, 2009; Brito & Ball, 2020) illustrating the importance of active, reflective, and sustained professional learning (p. 1). Generative change refers to teachers' ability to apply prior knowledge and personal understandings to new topics and situations—a dynamic folding in of new awarenesses with existing teaching practices to adapt to students' evolving learning needs. Ball (2009, p. 48) coined the term *generative change* to describe teachers' ongoing learning and professional transformation, explaining that knowledge becomes generative when a teacher makes "connections with his or her students' knowledge and needs and begins planning the teaching based on what he or she is learning." The process is not linear but iterative, marked by critical reflection and continual reshaping of professional identity.

Overall, the program positioned the participants as active learners. We introduced them to CT as an expressive meaning-making practice and invited them to reflect on their own learning while exploring opportunities for connecting CT with their students' learning. Then, we looked at the CT teaching practices they implemented in their classrooms.

Participants

Participants in the larger study were elementary level classroom teachers, specialists, and one elementary school principal (n = 28). Teachers had an average of 12.5 years of experience. They worked in the same school district with many at the same schools. The majority of students in the district are non-white (80%), economically disadvantaged (70%), and 10% speak English as an additional language. Table 1 provides a summary of participant demographics in Cohorts 1 and 2. This article focuses on ten participants from Cohort 2 who taught in early childhood classrooms. All names are pseudonyms.

Data Collection and Analysis

Qualitative methodologies (Lincoln & Guba, 1985) guided data collection and analysis for this paper. Data was collected from cohort two of 10 participants. Data included interviews (post-institute & post-observation), field notes, photos, videos from classroom observations, and related artifacts over nine months. Post-institute interviews captured participants' reflections on their learning during the institute and intentions for implementing CT in their classrooms. Classroom observations took place in the fall and spring, followed by post-observation interviews. Classroom observations were videotaped and during interviews, participants viewed their videos and reflected on their instructional decisions and student learning (Cherrington & Loveridge, 2014). Field notes and artifacts captured interactions during the institute and yearlong activities and artifacts provided tangible examples of pedagogical decision making (e.g. community agreements, sentence starters, student expert badges).

Data analysis occurred in several stages, following a systematic coding process (Hatch, 2023). All interviews were transcribed verbatim. Field notes were typed and formatted. Photos and videos were organized, labeled, and saved on a secure database. In the first stage, we read and re-read all transcripts and field notes and jotted down broad observations and ideas. Photos and videos were viewed multiple times, where we noted specific elements such as teachers' verbal interactions, gestures, spatial arrangements of the room and students' interactions. We used open coding (Saldaña & Omasta, 2016) on the interview transcripts (N = 30) and field notes, segmenting text into small, meaningful units (e.g. phrases and sentences). For interview and field note analysis, we collaboratively used Taguette, a free, open-source qualitative research tool (https://www.taguette.org/). We labeled words, phrases and paragraphs with initial codes and then consolidated codes into 15 categories (e.g.

Table 1 Participant demographics, Cohort 1 & 2 (N = 28)

Cohort 1 June 2021 – May 2022 (n = 13)		Cohort 2 June 2022 – May 2023 (n = 15)	
10 Females(8 White, 2 Latinx) 3 Males(2 White, 1 Asian American)		13 Females(4 White, 9 Latinx) 2 Males(1 White, 1 Asian American)	
Teaching Level	n	Teaching Level	n
Pre-K	1	Pre-K	2
Kinder	4	Kinder	4
1st Grade	0	1st Grade	1
2nd Grade	5	2nd Grade	2
Admin (Principal)	1	4th/5th Grade	1
Specialist	2	Specialist	5
Teaching experience	n	Teaching experience	n
1–3 Years	3	1–3 Years	3
4–8 Years	2	4–8 Years	2
9–18 Years	8	9–18 Years	10

student awareness, identity, implementation, shared community, notice and naming, student learning). For example, the following phrase was coded as *awareness* "almost every other time, he has cried just out of frustration, but he was, I mean he really had a plan and stuck with it."

During the second stage, we used axial coding (Creswell, 2010) to compare codes and identify connections, looking for relationships and context-related associations. We grouped and condensed codes into themes and sub themes (e.g. *community development*, *awareness of students' learning and dispositions*, *CT and students' linguistic abilities*, *connecting to multimodalities*) and developed a code book that included titles and descriptions for each theme and sub theme. Using our code book, we analyzed the photos, and videos by labeling photos and timestamping videos. In the third stage, we focused specifically on teachers' awareness of students' learning and dispositions- instances where teachers explicitly described how and why they focused on students' strengths and abilities. To ensure consistency of findings, we collaboratively worked on all stages of the analysis, discussed discrepancies, and agreed on the themes presented in this paper. To ensure reliability, we triangulated our data by cross checking the findings from interviews, field notes, photos and videos. Member checks with participants were conducted at the end of the year, and findings were amended accordingly (Table 2).

Researcher Positionality

As teacher educators we work in complementary educational fields, literacy and art and share a commitment to culturally relevant education. This study emerged from interests in the contrasts (and contradictions) between learning to teach in expressive domains such as art and writing, and in domains normally thought of as less expressive, such as computer science and STEM. Our individual research looks at education from equity and inquiry perspectives, where teachers' identity work empowers and sustains their learning as well as that of their students and their students' families. In the next section, we describe two overarching themes that illustrate the ways in which participants implemented asset-based pedagogies while teaching CT in their classrooms.

Findings

Social Learning in a Classroom Community

All the participants described the ways in which social learning as an asset-based practice supported students' understanding of CT. They intentionally created a learning community where students collaborated and learned from each other. For example, a second-grade bilingual teacher explained how she stressed the importance of community with her students.

> The story I tell them is that if there's a race, …and the winner [is] going to get some candy…. [The] kids decided they all wanted to win, so they held hands and all rushed together so they could all share the gift—they didn't want to leave anyone behind. If you know something, share it with your buddy. Everyone has to get there together.

Many attributed their focus on community building to the summer institute. They recalled how everyone gathered in a circle each morning to share ideas, explore new concepts, and model interdependence. One teacher remembered, "One of my favorite parts of the institute was the morning circle … I really felt connected to the other participants and that we were all learning together." When asked how it related to learning CT, another teacher explained, "I felt vulnerable going into this institute- I didn't know anything about CT. But you (Assaf & Justine) created a safe space of us to take risks and learn together." Similarly, others believed that learning in a community provided excellent opportunities to nurture how students helped each other learn CT—more so than most of their direct-teach lesson requirements where the teacher "does all of the talking" and "students are told what to do and how to do it."

Table 2 Data collection and analysis

Year long PD	Data collected	Tools used	Analysis
Summer Institute	Field notes Photos Videos Post Institute Interviews	Microsoft Documents Phone camera Zoom Video Conferencing Verbatim transcriptions Taguette	Open coding, constant comparative analysis, photos, and videos organized and labeled and coded
Classroom Observations 1& 2	Post Observation Interview Field Notes Video and Photos	Microsoft Documents Phone camera Zoom Video Conferencing Taguette Code Book	Open coding, constant comparative analysis, photos, and videos organized and labeled and coded

Once in their classrooms implementing CT, many teachers noticed that their students helped each other without being coached or asked to do so and that it seemed instigated by two things: the computational materials and how they encouraged collective sharing. In one classroom, the students just started helping without being coached by the teacher. The teacher explained, "They (students) really do help each other in the classroom…. If somebody needs help, they're really sweet. … And from day one, it's like when your friend needs help, we're gonna help them out. It seemed to happen more during Scratch time, kids would just call out 'can anyone help me?'" Other teachers noticed how their intentional focus on building a learning community supported students' collective problem solving while engaging in CT activities. A first-grade teacher explained, "What I learned about it—in the sense of debugging—…[was] how well they used their language to collaborate with each other and try and debug [together]. This sort of self-initiated helping doesn't always happen during other times in our day."

Several teachers talked about mimicking what they learned during the summer institute and how that experience prompted them to create similar experiences for their students:

> Participant: I told that kid, "Can you show them what you did?" Because that's something we did at the institute. When I didn't know something, I would look around [to find] which teacher looked like they're successfully moving on, and then I would ask them, "How did you do that?"

Teachers believed that the simple act of students helping each sustained a stronger community of learners and enhanced students' CT learning. By telling students to ask their peers for help (and not the teacher), teachers were creating a learning environment where everyone was positioned as an equal and valued learner. This is important because it moved the need for expertise out of the teachers' role and put it into the students' domain.

Another aspect of social learning showed up during group sharing. Teachers invited students to participate in group sharing during and after CT activities. For many, the sharing was purposeful—it invited students to show their creations and talk about their learning processes, as well as to ask for help and problem-solve together. A kindergarten teacher explained how she created opportunities for students to articulate their design decisions and read the code.

> We try to wrap up our coding with sharing.… We usually try to do at least one prediction [where students guess the code after watching the animation]. I usually try to do a pretty simple one, that I can predict…without looking at it myself. Because I do think it's important that they're able to kind of put those together. And I like when the kid who wrote the code knows what they wrote, and they're like, 'No, it's not that.

When students shared, they also showed how much they knew, which reinforced asset-perspectives of the students.

For others, sharing during CT time was similar to author's chair (Graves, 1990) during writers' workshop, where students read their writing and received peer feedback. CT group share time was no different. Students projected their coding projects on the digital screen or showcased their robot on the floor and shared them with the whole class. Students asked questions like "How did you change the background? or "Can you show me how you coded your KIBO to flash it's light?" During group sharing, teachers typically positioned themselves away from the front of the room, physically removing themselves from the group, thus giving students authority over their work (Fig. 2).

Providing time and a structure for students to share their CT projects affirmed students' identities and voice, and emphasized process over product, as a first-grade teacher explained: "Well, they all want to be seen, they all want to be heard. They want to show off what they feel successful at, or they need just that extra boost of confidence [from sharing]." Collectively teachers noted how much students appreciated

Fig. 2 Group sharing time. Lori Assaf photographer

sharing—"They love it"—and said they continued to create opportunities for sharing because students demanded it.

Throughout the year, we noticed teachers' and students' discourse shift to be more collectively inclusive by using pronouns like "we," "us" or "our." For example, when of the pre-kindergarten teachers passed out the KIBO material boxes, she recalled the students chanting "'Let's do this! Let's do this!'" Likewise, another teacher described how she nudged her students to work together while exploring circuits. "I heard them saying, 'It's not working.' I'm like, 'Well, what happened? What can we do?" The repeated use of pronouns such as "we and us" illustrates how the teachers and students viewed their collective learning of CT and their identity as learners. Likewise, by using collective pronouns, the teachers positioned the students as collaborators not competitors and invoked a way of exploring together in the classroom that acknowledged and supported all abilities and interests. Many teachers became aware of how they changed the way they talked about helping their students—for instance, instead of jumping in and telling students, "This is how you do it", teachers began by asking "what do we notice?" or "what do we want to change?" As such, teachers' statements became questions and invitations for students to solve problems together. Similarly, students' language became more inclusive when they helped other students or when they talked about projects with peers, which may have influenced relationships among students and consequently shaped the ways in which they viewed their learning of CT.

Becoming Aware of Students' Engagement, Interests, and Abilities

This theme illustrates how the teachers consistently expressed a sense of surprise and excitement about how quickly and easily their young students engaged and collaborated in CT activities and how CT provided multiple modes of meaning making. They emphasized students' engagement, interests and abilities by explicitly naming and positioning them as experts in their classroom. For example, teachers wrote students' names on the board, listing them as experts in specific CT abilities (Expert in Algorithms or Audio Expert). Many created and passed-out expert name tags to students both to recognize their abilities and to give them authority in the classroom. One kindergarten teacher explained, "They have these little name tags that say that they're the coding teacher for the day." Centering the students' experts was an intentional practice and shifted how CT was being implemented in the classroom (Figs. 3, 4).

In addition to naming student experts in the room, the teachers intentionally encouraged students to seek out experts in the room. One first-grade teacher explained:

Fig. 3 Image of teacher naming expert. Teacher pointing out name of student who is ScratchJr character expert. Photographer Lori Assaf

Fig. 4 Image of student expert teaching class. Photographer Lori Assaf

> Ask me a question, even in ScratchJr, and I'm like, 'Oh. Hold on, friends. I need your attention. Somebody's got a question. He needs to know something about the backdrop, or he has a question on a Sprite. Anybody here an expert on Sprites?

Others shared how surprised they were with some of their "striving learners" who tended to give up or quit when learning became difficult. A second-grade teacher explained,

> I won't name names, but this student struggles to do anything alone during reading time but when we pull out the iPads and start working on our Scratch projects, he is so engaged and runs around helping other students... I'm so proud of how quickly he has learned and how the others see *him* as the expert.

As teachers named and positioned their students as experts in their classrooms, they reinforced the need for students to help and teach each other. They explained how their instructional practices and management of students' behavior shifted and how leveraging student experts shifted the roles and responsibilities of learning and teaching CT in their classrooms. For many, this shift became more trusting and less directive. For example, one first-grade teacher reflected on how she was changing her instruction.

> I would say my approach has changed a little bit … because in the past I would have gone with the traditional 'I do, we do, you do.' And with this, especially with the KIBO, I felt myself [changing] because I give them a few minutes and then have them come back together. 'Okay? Well, what did we notice? What didn't work out so well? How can we fix it?' Like, guiding them in those discussions without the 'I do, we do.' It was straight to the 'you do'—you figure it out.

By recognizing how quickly their students were learning CT and how capable they were of solving problems and supporting one another, the teachers did not need to be the CT authority or "know everything." In fact, many of them shared that releasing expertise was a relief. Not knowing allowed them to create spaces for their students to learn from each other. One Pre-K teacher explained,

> And it's okay that I'm not the teacher. I think that was the main thing I got out of the [program]. That I'm not the answer of all things. And so, really taking a step and being just somebody on the side and having them learn through each other.

Allowing students to collectively problem solve and help one another was similar to how the teachers learned CT during the summer institute. They used phrases such as "What do you think?" or "Who can you ask for help?" instead of simply giving them the answers. This shift in support became intentional as teachers became more aware of students' strengths and engagement while participating in CT activities.

Discussion

This study addresses a gap in early childhood CT education by documenting the emergence of asset-based pedagogies in participants' classrooms. That is, we did not mandate asset-based approaches during the learning program nor tell teachers what CT activities to do with their students or how to do them. Nevertheless, findings reveal that teachers adopted asset-based pedagogies when teaching with CT tools and materials. Teachers recognized that an asset-based approach to CT instruction empowered not just their students but also themselves. Teachers talked about moving away from being the sole experts to becoming facilitators of a learning community and noticed that shifting their position in the classroom enhanced student agency. This move fostered a more dynamic and collaborative learning environment and, broadly speaking, made the teachers happier because they loved seeing their students collaborate and learn together (McCann & Yadav, 2023).

Asset-based CT practices enhanced social learning and community building in the classroom. Teachers described how their students developed a shared responsibility towards learning CT as they became more collaborative and learned from each other, which amplified their engagement with CT activities and nurtured the teachers' commitment to implementing CT in their classrooms (Scott et al., 2015). Throughout the year-long project, teachers expressed surprise at the ease and enthusiasm with which young children engaged in CT activities. They named students' expertise through their speech and physical props (expert name tags and posters). Such language worked to positively position students in relation to one another and invited asset-based identities (Kayi-Aydar & Miller, 2018).

Positive outcomes (e.g., collaboration, engagement, student abilities) from using asset-based CT approaches convinced the participants that young learners are more capable of complex thinking and problem-solving than they had assumed. Whether attributable specifically to the summer institute or to a combination of other factors (e.g., other components of the program such as meetups or coaching sessions, or to teachers' prior exposure to inquiry-based learning), findings suggest teachers' adoption of asset-based approaches influenced classroom dynamics and transformed their roles and identities—from expert to non-experts, from direct-teaching to designing inquiry and play experiences. As teachers enacted asset-based principles, they began to talk about how decentralizing their authority in the classroom opened a way toward collaborative learning in a classroom community. This shift, they said, had been influenced by their own learning experiences during the program (Postholm, 2011) and by their observations of the impact CT was having on student engagement and agency.

In this study, findings show that participants' adoption of asset-based pedagogies positively affected early childhood education in their classrooms. By homing in on what students can do rather than what they lack, teachers can better support students from marginalized communities, potentially reducing achievement gaps and inequities in CT and related CS fields (McCann & Yadav, 2023). By leveraging students' existing knowledge and abilities, teachers can make learning CT more engaging and therefore lay a strong foundation for future and advanced CT learning. The significant role that community and collaboration played in enhancing young students' CT learning in this study suggests that asset-based pedagogies can and should move CT learning beyond individualistic, competitive approaches to embrace more collective, supportive learning dynamics. Teachers' own learning experiences, and their recognition of their students' successful CT learning suggest there is more to learn about how to model and teach these approaches in professional learning programs for teachers. Future research should explore ways in which asset-based pedagogies can be deployed more widely and the impact they have on early childhood teaching and learning..

Expanding the implementation of asset-based CT pedagogy across different contexts and age groups to explore its broader applicability and impact.

Investigating the long-term effects of early exposure to material inquiry approaches and its impact on students' CT skills, attitudes towards computing, and overall academic trajectories.

Exploring professional development models that prepare educators to adopt and implement asset-based teaching practices that privilege expressive meaning making and purposeful play in CT.

The ease with which young children can grasp and engage with CT concepts when taught in a context that values their insights, backgrounds, and experiences is noteworthy.

The potential for asset-based pedagogies to transform not just the way CT is taught but also how subjects across the curriculum are approached, with implications for broader educational reform.

Conclusion

By using asset-based CT pedagogy, teachers supported students' identity and increased their engagement and interest in CS (Madkins et al., 2019). Students not only viewed themselves as capable and engaged CT learners, but also witnessed their peers develop similar confidence and abilities. Teachers gained a deeper understanding of inequities in computing and provided instruction that challenged deficit beliefs that too often oppress and limit students who have been historically marginalized (Scott et al., 2015). Asset-based pedagogy served as a catalyst for change in how early childhood teachers viewed students' abilities and how they integrated CT.

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Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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