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Elementary teachers' experiences in online professional development for literacy-focused computer science instruction for all learners

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ABSTRACT

Background & Context: This research focused on an online professional development (PD), the Inclusive Computer Science Model of PD, to support integrating computer science and computational thinking for all learners into K-5 literacy instruction.
Objective: This research was conducted to understand elementary teachers' perceptions of the PD.
Method: We used a qualitative case study methodology to collect multiple sources of perception-focused data from 10 purposefully selected participants in the PD and used a general inductive approach to data analysis.
Findings: Three themes emerged that focus on teachers' perceptions, with multiple considerations for how teachers viewed the concept of computer science, the potential for students with disabilities to participate in computer science instruction, and how they considered UDL in this instruction
Implications: Findings have implications for the potential of computer science integration into elementary literacy instruction and how teachers may independently use computer science instruction that supports all learners in their future teaching.

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Computer science; computational thinking; literacy; elementary instruction; professional development

Introduction

With a growing focus on computer science to prepare all students for both the current modern, digital society and for the future, approaches to computer science instruction have become increasingly important in teacher education. As such, the research in this paper focuses on K-5 teachers' perceptions of their participation in an online bichronous (both asynchronous and synchronous) professional development focused on inclusive computer science education. The professional development was designed as a part of a larger mixed methods study to introduce the knowledge and skills necessary to teach computer science (CS) in classrooms that featured a diverse body of students, including students with high-incidence disabilities. High incidence disabilities (HID) are the most

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common disabilities and include learning disabilities, mild intellectual disabilities, high-functioning autism, and attention-deficit hyperactivity disorders (Prater, 2018). Previous research indicates additional strategies and support approaches may be necessary for the full inclusion of students with HID in computer science instruction (Hutchison et al., 2021, 2022). Thus, our professional development model emphasized approaches for supporting students with HID during computer science instruction.

Overall, our approach features a literacy focus, where CS, particularly coding, is viewed as a literacy skill. That is, we view coding as a way for students to communicate and to express themselves. We also focus on CS learning activities that are incorporated into existing curricula, as opposed to creating additional, stand-alone instruction. As such, we designed a model of professional development (PD), the Inclusive Computer Science model of PD, that is intended to not only train teachers to help students learn about computing and CS, but to also use CS as a lens with which to learn existing subjects such as language arts, mathematics, humanities, and science.

This PD project supports the national educational movement in the U.S. to include CS as a mandatory part of the curriculum in K-8 public schools as well as the broader global focus on computer science in education. Our approach starts by helping students understand the fundamental concept of computational thinking (CT) as a problem-solving approach that yields a solution that uses computation or algorithms (Denning, 2017; Papert, 1980; Wing, 2006). For example, structured dances, sports, recipes, and simple processes like getting dressed in the morning all require CT. Our previous research found that students who developed CT knowledge before learning to code were more likely to succeed in the first university CS courses (Offutt et al., 2017), which speaks to the promise of early education in CT and CS. Our PD builds CT knowledge early, then prepares teachers to integrate elementary coding skills using block-based programming languages such as ScratchJr and Scratch into instruction as a part of CS.

With many U.S. states rapidly introducing CS standards for the elementary grades, understanding promising approaches for teaching computer science in the elementary grades is more important than ever. A recent report from Google and Gallup (2020) indicated 75% of school superintendents believe that offering computer science instruction to students is just as important as offering instruction in core curricular subjects. Although CS opportunities and awareness in K-12 instruction are increasing (Google LLC & Gallup, Inc, 2016), they still are not universal. This is largely due to a lack of teachers who are prepared to teach computer science (Google LLC & Gallup, Inc, 2016). Thus, more work is needed to better understand approaches for preparing teachers to provide CS instruction, particularly in the elementary grade levels where computer science concepts must be integrated into other content areas due to the overlapping and interconnected nature of elementary learning in the content disciplines (Colwell et al., 2022).

The key challenge we addressed with the Inclusive Computer Science model of PD used in this study is that elementary school teachers need help learning how to teach CT and CS to their students, particularly those with high-incidence disabilities (Hutchison & Evmenova, 2022; Hutchison et al., 2021, 2022). To do so, we developed online, interactive, and asynchronous PD modules for teachers to learn the knowledge and skills needed. These modules (Hutchison et al., 2021) included both the knowledge that teachers need and specific presentations and exercises that can be used in the classroom. Additionally, we provided teachers with detailed CT and CS lessons that they could readily integrate into their literacy instruction. We also provided synchronous virtual opportunities for teachers to engage in online learning communities to unpack their learning and experiences using CT and CS lessons and instruction.

An essential aspect of our model of PD is that it highlighted knowledge for how to present the material to students with high-incidence disabilities through Universal Design for Learning, a framework to enhance teaching and support inclusive and accessible learning for all students regardless of their abilities and needs. As a result, the in-class instruction supported by the PD included specific, built-in, accommodations for such students. This approach to PD is currently not widespread. Just as it was important to understand the viability of the PD, which we examined in a related but different study, it was also important to consider teachers' perceptions of participating in the PD, as these may be an indicator of the likelihood that teachers will continue to utilize it (Ng et al., 2010). Therefore, this paper presents results from a qualitative case study (Merriam & Tisdell, 2016) focused on elementary-level teachers who participated in 10-months of professional development, consisting of online bichronous training and then teacher integration of the CS and literacy-integrated lessons into their classrooms.

Review of literature

The elementary grades are critical time points during which students begin to develop positive associations and attitudes toward computer science (Century et al., 2020). However, the elementary years can also be a challenging time to implement computer science standards both for teachers who are often unprepared to teach computer science (Rich et al., 2017), and for students who are overwhelmed with other subject areas, such as literacy and mathematics, for most of the school day (Century et al., 2020). Mason and Rich (2019) advocate for the need for professional development to help teachers gain confidence and competence to teach computer science to their elementary students.

Ways in which instruction occurs within elementary classrooms varies (Yadav et al., 2016); some instruction is designed to teach computer science independently from the traditional curriculum or in a separate specialty course (i.e. STEM, Computers & Technology), while other approaches integrate computer science into subject areas traditionally covered within the elementary curriculum (i.e. literacy, mathematics, social studies, science). For example, Kwon and colleagues (Kwon et al., 2021) developed computer science-specific units for elementary students that focused on an introduction to block-based coding and a project-based learning applied coding project. This computer science instruction was separate from the traditional subject-area disciplinary instruction in the elementary curriculum, and instead it was part of the school division's social-emotional curricular goals. On the other hand, there has been a recent movement (e.g. Century et al., 2020; Hutchison & Evmenova, 2022) to reduce the burden and cognitive load on in-service teachers by integrating computer science standards into lessons within subject areas, such as literacy, where elementary educators often report the greatest domain-specific self-efficacy for content and pedagogy (Gerde et al., 2018).

Integrating computer science and literacy

There is a natural connection among literacy and computer science that makes it well-suited for integrating computer science. For nearly two decades, literacy scholars have been arguing that literacy and English language arts teachers are responsible for teaching students the dominant forms of communication (e.g. Hutchison & Reinking, 2011; Kress, 2003, 2010; Leu et al., 2004), and coding is fast becoming a dominant mode of communication. New literacies scholars argue that it is essential for literacy teachers to instruct students in the strategies, skills, and dispositions associated with digital forms of communication (Hutchison et al., 2016; Leu et al., 2004) so that they can apply those to new technologies as they emerge. As coding emerges as a ubiquitous form of communication, it will be increasingly important for literacy teachers to understand basic concepts of computer science and instruct their students in the associated methods and skills. Previous research indicates that connecting new concepts to topics in which students and teachers already have background knowledge may make it easier for teachers to teach content that is unfamiliar (Hutchison et al., 2022; Ottenbreit-Leftwich et al., 2022). Accordingly, the lessons developed and provided through the professional development presented in this paper used literacy as a foundation for teaching students about computational thinking and coding. Additionally, research in literacy integration suggests the importance of understanding teachers' beliefs, perceptions, and reactions for successful integration of literacy with other content areas (Colwell & Enderson, 2016; Hall, 2005; O'Brien et al., 1995).

Online professional development in computer science

The professional development provided through this study was led in an online bichronous format. Following the most recent push for online teaching and learning that resulted from the COVID-19 pandemic, it is clear that online professional development will continue to be an "integral part of this new global educational landscape" (Bragg et al., 2021, p. 1). Online professional development has been shown to increase participants' content knowledge and pedagogical content knowledge, in addition to their self-efficacy and beliefs, about the subject matter covered in the professional development (An, 2018; Bragg et al., 2021). Moreover, in their systematic review, Bragg and colleagues (Bragg et al., 2021) identified design elements that were critical for online professional development success, including a focus on learner supports and individual differences in learners, engagement, flexibility, practical learning activities, relevance, application of knowledge and skills, and reflection.

Each of these design elements provide critical, holistic, support for online professional development. Yet, some have been specifically identified as essential for online professional development that is focused on computer science and computational thinking including focusing on learners and individual differences among learners, practical learning activities, and application of knowledge and skills. For example, professional learning communities were essential learner supports for generating excitement and helped to break down "the isolation that many computer science teachers feel" (Goode et al., 2020, p. 57) and for instilling a "culture of trust, respect and sharing" (Goode et al., 2020, p. 58). Indeed, PLCs are a consistently cited critical support for professional development in computer science (Menske, 2015; Ni et al., 2021). Further, Ketelhut and colleagues (Ketelhut et al., 2020) examined how elementary teachers applied their knowledge and skills in computational thinking following a sustained professional development opportunity. Participants not only provided examples of ways in which computational thinking was modeled in their professional development instruction, rather, the ideas they shared came from their own interpretation of knowledge, skills, curriculum, and pedagogical strategies that were developed through implementation in their own classrooms.

We used these considerations and other insights and directives gleaned from the literature base to design the current PD experience. Although we reviewed multiple studies related to computer science PD, we found two major reviews of literature to be highly useful for a streamlined and encompassing focus on powerful descriptors of successful computer science PD. For example, Menske (2015) review indicated the need for collaboration between higher education and local school organizations in the development of computer science PD to promote sustainability. Ketelhut et al. (2020) also recommended this type of collaboration. Thus, the current research utilized a year of planning efforts between school division personnel and teachers and university faculty to develop the final PD model (see Hutchison et al., 2021 for a comprehensive overview of the design process). Menske also noted that PD must have a significant duration for teachers to learn and practice new strategies and instruction. Teachers in the current study engaged in a year-long PD effort to grow, support, and sustain their efforts to integrate computer science into elementary literacy instruction. Ni and colleagues' (Ni et al., 2021) review enhanced Menske's findings to provide more current recommendations, particularly relevant to elementary settings. Their recommendations highlighted not only the benefits of PLCs for ongoing teacher support but specifically noted the usefulness of resource repositories, online spaces, and flexibility to support teacher collaboration, all of which our study integrated. Additionally, Li et al'.s review provided evidence that school-university partnerships for designing PD, such as the partnership in the current study, can be beneficial for designing successful PD models.

Finally, although there are a growing number of studies focused on professional development on elementary computer science, we were unable to find any studies that also focused on the inclusion of students with high-incidence disabilities. Thus, we had to develop a new approach based on existing literature on approaches to supporting students with disabilities broadly. We focused on teaching about and designing lessons with the Universal Design for Learning Guidelines (Center for Applied Special Technology CAST, 2018), which we describe in the next section.

Accessible computer science instruction for all learners

Accessible instruction for all learners regardless of their abilities and needs has received an increased interest all over the world. The global phenomenon of inclusive education can be found in most countries (Hernández-Torrano et al., 2020). Educators everywhere are working to make education available for students with disabilities alongside their typical peers (Reynolds et al., 2014). In the United States, the National Science Foundation (NSF) has supported numerous projects aimed at making CS inclusive for all. Some challenges that students with HID may face are difficulty in processes that affect participation in CS such as attention, memory, sequential processing, higher order cognition, visual-spatial functions, and language (Baker et al., 2003; Graham et al., 2017; Gregg & Mather, 2002). These students may also have difficulty planning, generating text, and making meaningful revisions (Graham et al., 2011). One way to approach designing an inclusive and accessible curriculum is through application of the Universal Design for Learning (UDL) principles and check-points. The premise of the UDL framework is to proactively and intentionally remove barriers for learners by providing multiple means of engagement, representation, and action/expression. From a UDL perspective, it is the curricula that is disabled and requires fixing, not the student (Cook & Rao, 2018; Rose & Meyer, 2002). This approach is especially important when teaching CS, which has historically not included women, people from different cultural backgrounds, and individuals with disabilities (Israel et al., 2017). Applying the UDL guidelines ensures greater equity and inclusion in CS. It offers necessary supports for students with disabilities who might be disengaged during computing activities (Snodgrass et al., 2016). All three principles can be built into the elementary CS instruction to support the broadest range of learners (Israel et al., 2020). The current study was designed to support students with disabilities in inclusive classrooms by providing teachers with professional development on designing instruction with the UDL principles guidelines, as well as providing them with ready-made lessons and materials that were designed with the UDL principles and guidelines. Having lessons that are pre-designed with multiple means of engagement, representation, action, and expression based on UDL principles is important for ensuring that a variety of options are available to students with varying learning needs.

Examples of how UDL guidelines were represented in the lessons include specific points in the lessons where: (a) students were provided with checklists to self-monitor progress on coding tasks (engagement); (b) student choice for the level of challenge in their coding tasks and for personalizing content to their own lives (engagement); (c) providing explicit prompts, organizers and lists for sequential steps when planning a project and when coding (representation); (d) chunking information into smaller parts (representation); (e) pre-teaching vocabulary and symbols, providing or activating relevant background knowledge, and making connections among ideas explicit (representation); and (f) providing multiple options for expressing ideas, such as text, speech, storyboards, and drawing (action and expression). Numerous tutorials, templates, and step-by-step guides were provided to scaffold the coding process. The instructional materials were designed to provide enough variation and alternatives to suit students who exhibit a variety of abilities, needs, and preferences.

Method

A qualitative case study approach (Merriam & Tisdell, 2016) was used to frame and organize data collection and analysis. The case was bounded (Creswell & Poh, 2017) by the focus on elementary teachers' perceptions of the ICS Model for PD in one year of a three-year project. IRB approval was granted by [university blinded for review; reference #XXXX]. A general qualitative inductive approach for analyzing data (Thomas, 2006) was used to identify emergent themes related to the following research question:

> What are elementary teachers' perceptions of the ICS Model for PD that targets literacy-focused computer science instruction for all learners, including those with high-incidence disabilities?

We believe teacher insight and voices are highly relevant to understanding potential effectiveness of PD and multiple studies in computer science education support this potential (Cutts et al., 2017; Mouza et al., 2017). By understanding how teachers view PD, PD may be enhanced and provide a more nuanced view of why teachers make the instructional decisions they do, based on their PD experiences.

Context & setting

This research was conducted in the final year of the project focused on developing a model of professional development, titled the Inclusive Computer Science Model for PD, for integrating computer science into elementary instruction. This model had a particular focus on supporting students with high-incidence disabilities in inclusive classrooms. The first two years of the project were used to develop and refine the PD model using design-based implementation research (see Hutchison et al., 2021). This third year focused on implementing and studying teachers' perceptions to the final PD model. The professional development content was implemented in online classroom settings due to the COVID-19 pandemic, and as such the

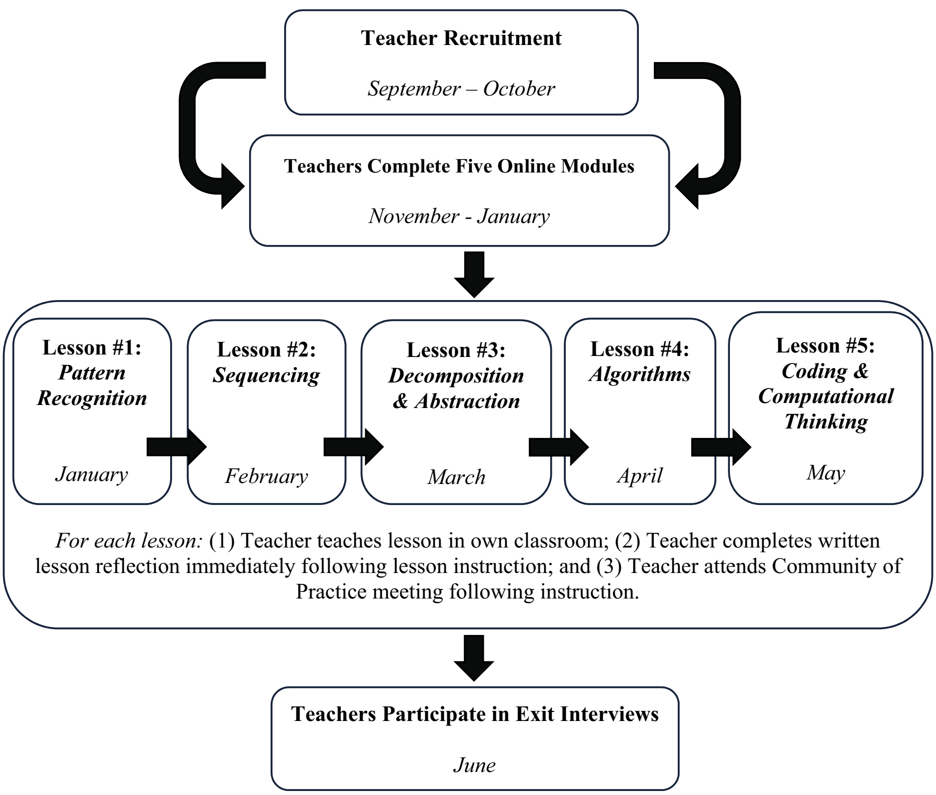

Figure 1. Inclusive computer science model of PD year three components & timeline.

model was 100% virtual. Figure 1 depicts the timeline of professional development components that were implemented online within the third year.

The school division in which the professional development took place was in the Mid-Atlantic region of the U.S., with all but one participating school receiving federal Title I funding to support students from families that are economically disadvantaged. Teachers in this study used Zoom as the platform for their virtual classrooms. Table 1 breaks down the major components of the Inclusive Computer Science Model of PD and provides an overview of what the PD entailed for the teachers in this study.

As described in the table, the PD included five learning modules that teachers worked through and then implemented corresponding lessons into their instruction. The five learning modules focused on the following topics and guiding questions.

- **Module 1**: Computer Science (CS) – What exactly is it and why is it important?
- **Module 2**: Computational Thinking (CT) – What is CT and how is it relevant to you and your students?

Table 1. Components of the inclusive computer science model of PD.

Component	Explanation
Online Modules	Participants completed five online modules prior to integrating computer science instruction into their classrooms. Modules were asynchronous, self-paced, and each module could be completed in 2–3 hours. Modules were focused on the following topics and built in complexity to help guide teachers into the ways in which computer science and computational thinking concepts can be integrated into their current curricula: (a) Computer science and its importance; (b) Computational thinking and its relevance to elementary students; (c) Coding and plugged activities to incorporate computational thinking; (d) Universal Design for Learning (UDL) and its use in classrooms; and (e) Integrating computer science standards into existing instruction. Through multimodal instructional resources (e.g. video, text, figures, external web resources), each module introduced participants to pertinent vocabulary and definitions, examples of unplugged and plugged activities related to the module content, content understanding checks, and opportunities to practice learned content. Teachers responded to closed and open response questions and created their own coding projects to practice module objectives.
Pre-Developed Lesson Plans	Five multi-day lesson plans were developed by the authors and research team for each K-5 grade level. All lessons: (a) Fused computer science and literacy instruction with state standards of learning; (b) Used UDL principles of learning to support all students; (c) Introduced a new computational thinking skill while supporting previously introduced skills; and (d) Provided gradual release of responsibility, beginning with unplugged lessons, moving to plugged lessons with whole-class coding activities, and then independent coding activities for individual students.
Teacher Integration of Lesson Plans	After receiving the lesson plans in Spring semester at the beginning of each month, teachers decided when and in what area of their existing instruction they would integrate the lesson plans. There was flexibility regarding when in the teachers' schedule the lessons would be taught; however, teachers were highly encouraged to teach the lessons prior to the relevant Community of Practice meeting at the end of the month. Teachers had the freedom to use the lessons verbatim as provided in their instruction or to adapt the lessons to fit their instructional comfort level, teaching style, and content of instruction.
Lesson Reflections	Teachers completed lesson reflections promptly after integrating a lesson to consider highlights and challenges of the lesson and how students with disabilities participated in the lessons.
Community of Practice	Monthly, virtual community of practice meetings were held for teachers to preview the upcoming lesson and to reflect collectively on the previous lesson they taught. These reflections served to consider challenges in lessons and collective solutions for how they might be addressed. Between meetings, teachers were encouraged to contact members of their communities of practice via email, some of whom may have worked in the same school, or reach out directly to the research team for additional support.

- **Module 3**: Coding – How do I code and and how can I fuse CT concepts into plugged activities?
- **Module 4**: Universal Design for Learning (UDL): - What is it and how do I use it?
- **Module 5**: Integration of CS & CT – How do I integrate the [state blinded] standards of learning for Computer Science into my existing instruction?

Additionally, for context, we provide here a link to the project and lesson website that includes all lessons that the teachers implemented during the third year: (https://www.inclusivecomputerscience.org/copy-of-coco-video-lessons).

Participants

This research is a sub-study of a larger study that utilized mixed methods. In the larger study, 44 teachers in total participated in the ICS Model of PD during the third year of the project. For this research study, a sub-group of teachers were purposefully selected as participants to provide an information-rich qualitative case study (Patton, 2002) that could be closely analyzed through a smaller number of participant perceptions. Specifically, participants were selected that provided the most in-depth and thorough responses to interview questions. Additionally, the researchers aimed to select a sub-group with a range of years of teaching experience and all grade levels from the larger population represented. Consequently, 10 teachers were identified in the sub-group that comprised the case study. All identified as female, which also aligned with the larger population. Table 2 provides an overview of the selected participants for the case study. All names in this study are pseudonyms.

Data sources

Multiple sources of qualitative data were collected to address the research questions. As this research was focused on teacher perceptions, the primary source of data were semi-structured interviews collected after the project was completed. The interview protocol consisted of 20 open-ended questions and were conducted via Zoom or phone to follow COVID-19 pandemic protocol for social distancing. Interview questions focused predominantly on perceptions of various components of the PD such as, "What parts of the professional development did you

Table 2. Participant descriptions.

Participant	Role	Years of Experience
Cora	K-2 Teacher	2–5
Ebony	Grades 3–5 Teacher	6–10
Farrah	K-2 Teacher	6–10
Holly	Grades 3–5 Teacher	2–5
Jackie	K-2 Teacher	6–10
Laura	Grades 3–5 Teacher	11–15
Lillian	K-2 Teacher	11–15
Margaret	K-2 Teacher	6–10
Nafisa	Grades 3–5 Teacher	2–5
Tasha	Grades 3–5 Teacher	21+

Note. The participating K-5 teachers in this study taught a variety of subject areas (i.e. mathematics, social studies, science) within their classrooms, including English Language Arts.

find most useful and why?" and "How did your participation in the professional development influence how you thought about computer science and UDL?" Interviewers followed the protocol closely but could include follow-up questions or prompts to request clarification of statements or to prompt the participant to expand on their thinking to ensure ideas were captured appropriately. This practice served as a form of member checking to increase accuracy of participants' statements. Additionally, lesson plan written reflections, collected after all five lessons were implemented, supported triangulation of interview data and provided context to interview statements.

Data analysis

This research focused on investigating teachers' perceptions of the PD. An exploratory approach to qualitative analysis, specifically a general inductive approach (Thomas, 2006), was used to identify emergent themes. We selected Thomas' approach to identify emergent themes as it allows "research findings to emerge from the frequent, dominant, or significant themes inherent in raw data, without the restraints imposed by structured methodologies" (p. 238). Opposingly, as Thomas notes, in methods such as deductive analysis "key themes are often obscured, reframed, or left invisible because of preconceptions in the data collection and data analysis procedures imposed by investigators" (p. 238). While other qualitative methodologists, such as Strauss and Corbin (1998), concur with the importance of allowing themes to emerge from raw data in an inductive manner, Thomas breaks down the process in a step-by-step manner to provide a straightforward, systematic, and clearly defined general approach to inductive analysis that can readily be replicated. In turn, validity of findings may increase. It is for these reasons we selected this approach for analysis.

To follow Thomas (2006) approach, we first engaged in multiple holistic readings of all data. This required that all transcribed interviews be read collectively and comprehensively without coding or trying to determine codes. The purpose of this reading was to gain an overall understanding of the data. Second, we followed Thomas' coding procedures to identify meaning units, or text segments, and subsequent categories to define those meaning units in the lesson plan reflections and interview transcripts. Some meaning units were assigned to multiple categories, which is common in this process (Thomas, 2006). We illustrate our process in Table 3 by providing a sample data excerpt and its coded meaning units, categories, and theme.

Table 3. Sample coding procedure.

Data excerpt: With a pandemic, I know we're all like ***switching gears into a more technology-based learning***, so I knew my kids were going to be on the computers all the time, anyway, and ***I didn't really know anything about computer science***. At the same time, I think that our educational system is still antiquated, and how we're teaching we're still using a production line model, as opposed to empowerment by ***giving students the ability to identify problems, identify opportunities, and solve problems***.		
Meaning Unit: switching gears into a more technology-based learning	**Category**: Shift to technology	**Theme**: Evolution of Experiences with and Perceptions of Computer Science Instruction
Meaning Unit: I didn't really know anything about computer science	**Category**: CS perceptions	
Meaning Unit: giving students the ability to identify problems, identify opportunities, and solve problems	**Category**: Supporting student independence/ability	

After all data were coded, we refined categories and identified quotes that spoke to the core theme, or "essence" (Thomas, 2006, p. 242), of the category. These quotes were used for illustration in our results, which are presented in the following section.

Results

Teachers' perceptions of the professional development experience were holistically positive yet nuanced and evolved over the course of the study. Three themes related to perceptions emerged from analysis: (a) evolution of experience with and perceptions of computer science instruction; (b) broadening perceptions of students with disabilities and online CS learning; and considering explicit instruction in UDL. The following subsections further explore and provide data examples from the case study that highlight and expand on these themes with the intention to provide consideration for how teacher educators might further enhance CS instruction for elementary teachers.

Evolution of experiences with and perceptions of computer science instruction

A primary takeaway from analysis is that teachers' experiences in participating in PD focused on integrating computer science into elementary instruction are constantly evolving and are supported by a variety of factors. For example, some of the teachers' experiences became more positive as the PD progressed and their content knowledge built. As Lillian described:

> So, when I did the modules, I felt kind of shaky. Like I did all this work, and I don't really know that I know what this stuff is yet. Once we started doing the lessons, I felt a little nervous about it. But then, as I kept hearing the vocabulary and seeing it used and it just kept repeating on in the lessons. . .I mean it just built, you know? I just kept seeing [vocabulary] in use, then the lessons really helped me solidify. (Interview)

Lillian's experience, like others, began with trepidation but ended with more confidence toward CS instruction. This trajectory is to be expected as increased familiarity with CS content and lesson plan format may build comfort with using this type of instruction. Like Lillian, many expressed initial misunderstandings or shortcomings of knowledge surrounding computer science. Margaret explained:

> Working in the school system, I should know something about computer science and this pandemic made me more aware of how limited my understanding with my ability to maneuver and to find different things on the computer was, and I really actually had very little idea what computer science was. (Interview)

But as teachers progressed through the PD, their perspectives evolved to include a variety of content area connections. Jackie described, "Finding out what computer science actually is was really interesting . . . I kind of figured I could tie it into science, and I could tie it into math, but the ways that it was tying into reading, I thought it was really interesting" (Interview). These types of evolutions in considering CS in literacy are particularly of note as the PD was advertised as CS in literacy and English Language Arts and the teachers volunteered to participate. Such statements spoke to the value in experiencing this type of CS instruction through integrating the lesson plans and how this experience helped to promote deeper understandings of CS and literacy connections.

The experiences offered in the PD about how CS and CT might connect to literacy instruction enabled teachers to better consider what this type of instruction might look like in their classrooms, prompting an increase in comfort with using and adapting the lessons for their instruction. Ebony discussed:

> The lesson plans were useful again. Just like a recipe when I'm cooking now you know I read the recipe, but I like to add, what I want to add or substitute what I want to substitute. So I was, I felt comfortable doing that, with the lessons it was like a jumping off springboard where I felt okay, I see this now, I want to add this or I want to rearrange to that. (Interview)

Like Ebony's, a consistent theme in analysis indicated teachers' perceptions seemed to evolve as they implemented lessons and watched their students engage in CS and CT. Indeed, teachers' positive perceptions of how students engaged in CS seemed important in their future consideration of using such instruction and leads to the second theme that emerged in analysis.

Broadening perceptions of students with disabilities and online CS learning

Participation in the Inclusive CS model of PD was advertised as a learning opportunity that would support teachers in integrating literacy-focused computer science for all learners, with a particular lens on students with high-incidence disabilities, aiming to support a broad spectrum of learners for inclusive instruction. Accordingly, the teachers' voluntary participation in the PD indicated that it was likely that they were at least somewhat confident, or optimistic, that all students could engage in such learning. Yet, analysis revealed a consistent trend of teachers' surprise that all students could engage in the lessons and that often their students with disabilities thrived during such instruction. Jackie noted, "Students were familiar with coding, more so than expected" (Lesson Plan Reflection) and went on to elaborate:

> I think I had one student who struggled and then another student—before I could even jump in to help them—told them how to do it. That was on Scratch and then, even with the recognizing patterns, the one student who struggled with Scratch, was able to answer the more basic questions about recognizing patterns and where to find them that the other students. . .my regular students couldn't answer. And so, it really it was more open for all students of all learning abilities. (Interview)

The teachers also commented on how their experiences integrating the lessons provided positive examples of how all students can be engaged in literacy-focused CS learning through other content connections. For example, Holly, discussed how her perception about how students with disabilities could engage in CS drastically shifted through observing the lessons in action:

> I had this predisposition that a lot of times computer science was always for, you know, gifted high achieving students. But this year, teaching a cluster and presenting it to everybody, I was amazed at how engaged and how students with disabilities were on the same playing field as high achieving and gifted students. So, it was amazing to see for myself as an observation as a teacher that computer science really can apply to everybody. (Interview)

Such perceptions were found throughout interviews and allowed teachers to consider how all learners might thrive in literacy-focused computer science instruction.

In turn, teachers reacted to which contexts might best engage all students in CS as they participated in the PD and taught the lessons. The professional development was fully online, and most of the teachers implemented the lesson plans in an online context due to remote learning during the COVID-19 pandemic. Teachers indicated that the shift to online instruction prompted their enrollment and participation in the PD as they viewed computer science as something they could highlight with online instruction. Further, teachers considered that the temporary shift to an online learning environment might support an increase in permanent instruction focused on technology and out-of-school assignments, even after students fully returned to their physical classrooms.

However, after participating in the PD and implementing the lesson plans virtually, analysis indicated that teachers favored face-to-face instruction when teaching computer science concepts, particularly for students with disabilities, and many favored the unplugged CS lessons, which removed the computer technology aspect of some of the lesson plans. Laura stated, "This was my favorite lesson out of the five! Watching students make the connection that you don't have to be working with computers to have computational thinking was so gratifying. I think they really got it in this last one" (Lesson plan reflection). Such perceptions regarding unplugged activities and higher levels of support for all students in a face-to-face setting were common, even though teachers cited interest in the digital aspect of the PD as a motivating factor for participating in it. Elementary teachers' preference for face-to-face instruction is understandable and to be expected. However, the PD, for many, strengthened teachers' perceptions that (a) all students can participate in literacy-focused computer science instruction, but (b) face-to-face support and foundations in unplugged CS is critical for high levels of student engagement and success.

Explicit instruction in UDL

Universal Design for Learning was the framework used in the lesson plans and in the professional development experience to support teachers in engaging all learners in CS and CT instruction. Although UDL constructs were already integrated into the lesson plans for teachers to readily implement, these constructs were also explicitly highlighted in the lesson plans and teachers engaged in an online learning module at the start of the PD to support their understanding of UDL to promote future independent use. For example, Tasha stated, "My students with disabilities, my lower end students, and my higher end students – they were all engaged in the lesson because with the UDL design, you are able to meet their needs wherever they are" (Interview). These types of comments were positive indicators of the potential of UDL in elementary CS integration.

Yet, analysis also suggested that teachers struggled to explicitly identify areas of UDL or consider how to independently use this instructional design. Cora, when asked about integrating UDL into her future instruction, noted, "Oh, [I'm] not super confident. I feel like I just need to play around more and. Honestly, I'm not sure I paid super close attention to those [UDL strategies in the lessons]" (Interview). Nafisa also found it difficult to discuss UDL and how it could potentially be a part of her instruction. She discussed, "I would want to take like a full semester course on universal design to before felt comfortable using it as a planning device, personally just because I haven't had the opportunity to plan with it at all" (Interview). Nafisa did describe that UDL was a best practice that seemed like a natural fit to current teaching practices. However, similar to others in the PD, she felt that more practice and explicit attention to UDL was needed. Relatedly, teachers also noted the complexity of learning about both CS and UDL during the PD experience. Lillian explained,

> I was so busy trying to learn that [computer science]. I'm sure I did a bit ofUDL and it was there. I just don't know that I can always just specifically point it out, I guess. I might need a little more [practice] with that. It was two big principles. I felt like you've got your computational thinking and then you've got your UDL, and it was really two new things for me, and two very, you know, broad categories, so, I think I'll be honest and say I need a little more for the UDL (Interview)

Further, some teachers expressed misunderstandings related to UDL. Ebony attempted to describe how she incorporated UDL into instruction, but her description did not align with UDL constructs. She explained,

> [UDL is] just introducing what we're talking about what computer science is and how you know it's human to make things work in programs and they [students] can do it too. Just like what they're [students] using now - how all their apps work, how Tik Tok works, anything else someone actually programs. (Interview)

There was a consistency in statements such as these, particularly in post-study interviews, which were conducted after the PD concluded, that indicated teachers had become less familiar with terminology related to UDL. Analysis indicated that teachers were implementing UDL constructs, but explicit use and identification of UDL-related terminology was less apparent.

Certainly, it should be considered that because teachers were following pre-made lesson plans, their explicit understanding of constructs related to UDL were less of a focal aspect of this study than how they incorporated the lesson plans into their existing instruction. Yet, this theme is important as UDL was a foundational component of the PD and was explicitly featured in the online modules and lesson plans. While teachers did describe instructional constructs that could be considered UDL-related, understanding how teachers reacted to it and experienced learning about it/using it in the OPD was somewhat difficult to understand as teachers struggled to explicitly identify it and specifically describe how they used it.

Discussion & implications

Teachers' perceptions of participating in the online professional development focused on integrating literacy-focused computer science into their K-5 instruction revealed multiple insights into how teacher educators might consider planning future training for elementary CS instruction for all learners. Findings revealed ways that teachers benefitted from participation in this professional development, as well as ways that this professional development content and approach could be approved. As such, we discuss implications for future teacher education and professional development opportunities.

Extended exposure to multiple types of CS instruction

Two components of this PD that seemed to have the most influence on teachers' experiences were the extended length of time teachers spent in module-based training and the different types of CT and CS activities the lesson plans utilized. Providing teachers with extensive training in not only what CT and CS were definitionally but also different ways, both plugged and unplugged, to integrate CT and CS into instruction widened teachers' understandings of how these constructs could be readily and compatibly used in their instruction. Teachers who participated in this PD experience found the foundational components of CS for elementary students that were introduced in our modules to be highly beneficial. The range of CS and CT activities that were provided in the lessons also encouraged teachers who were less comfortable integrating CS on their own to persist and try new approaches in their instruction. By beginning with unplugged activities and then moving to plugged, coding-focused activities, teachers had the opportunity to gradually increase their comfort with CS integration and, over time, rely less on the scripts provided in the lesson plans. As Ebony indicated, the lessons served as an important "springboard" to help them redesign their instruction. Additionally, teachers independently found new ways to integrate CS and CT concepts into curricular areas other than literacy. This is an important finding of our study, since increasing teachers' independence in their instructional planning was an intended outcome of the project. Ultimately, with any curricular innovation or reform, it is critical for teachers to reconcile what is required of them with their own sense of good teaching and knowledge of their students' interests in needs (Bascia et al., 2014). Based on our findings, we believe it is the ongoing support provided by the lessons and time to integrate and refine what they learned that empowered teachers to begin making modifications to the lessons to best meet their students' needs and align the lessons with their pedagogical preferences.

Further, teachers' perspectives on integrating CS into their instruction became more positive as time went on, indicating the importance of extended professional development. The continued practice of implementing lessons with opportunities to discuss them in a community of practice ensured that teachers learned from opportunities to reflect on their own practice and to discuss their instructional practice with others. As Lave and Wenger (1991) suggested, learning cannot happen when knowledge and social practice are considered separate from one another. We agree with Menske (2015) and Ni et al. (2021) that the extended time to be part of and engage in supportive professional development may be particularly important for online professional development in CS since there are no face-to-face opportunities for collaboration or unplanned interaction and conversation as there may be with in-person professional development opportunities. Although online models may certainly be appealing for their flexibility, these models benefit from extended offerings of support, such as the year-long model in this study. While we posited prior to this research that the community of practice may be the most supportive feature of the PD, and teachers did comment informally to us that they enjoyed this feature of the PD, a standout feature that emerged from perception-focused data highlighted the extended time spent in the PD as more critical.

Considerations for computer science instruction for all learners

Teachers' perceptions of engaging all learners in CS, particularly those with high-incidence disabilities, were holistically positive, aligning with Ketelhut et al'.s (2020) findings. Analysis indicated constructive teacher-noted shifts in how they viewed students with disabilities and their ability to engage in CS, indicating the power of such instruction to better support inclusive learning environments. Further, teachers were impressed by and acknowledged how much their students with disabilities enjoyed the CS lessons, and despite the PD's focus on an asset-based mindset in teaching using UDL, teachers were surprised that, as one teacher noted, "CS instruction can apply to everyone". Based on the design of our PD model, teachers perceived that they were able to include all students and make the instruction apply to everyone because the lessons were carefully and strategically designed with UDL framework. Because this research was focused on teacher perceptions, we cannot speak to the actuality of the teachers' inclusivity and applicability of lessons. Nevertheless, we find their positive perceptions to be promising in that they were consciously considering all students' learning and how instruction could apply across student ability levels.

Additionally, designing the lessons with UDL in mind provided multiple entry points, ample choice, and many ways for students to engage with the concepts being taught and to represent their own ideas. For this reason, it is also important for us to note that, because the universally designed lessons were provided to teachers, some teachers struggled to specifically identify when and where they were using UDL. Although we provided teachers with content about UDL in our online modules, our findings indicate that providing teachers with pre-made lesson plans did not provide them with sufficient practice opportunities to become independent in designing instruction with the UDL framework. Thus, future professional development should ensure that teachers also have multiple opportunities to practice designing lessons with the UDL framework. In doing so, they may more independently integrate the UDL principles into their instructional practice once the professional development has ended, promoting more inclusive computer science instruction (Israel et al., 2017).

Finally, teachers in the current study indicated how their students with high-incidence disabilities were actively engaged in literacy learning during the CS-literacy integrated lessons. They indicated this engagement was a shift for students who struggled with reading and traditional literacy lessons, suggesting the power of integrating CS and CT into traditional elementary disciplines, such as language arts, to support all learners. Integrating CS into literacy instruction could be a way to motivate and engage students who have difficulty during literacy instruction, so this is a topic that should be studied in the future. This idea is also supported by previous findings (e.g. Ascenzi-Moreno et al., 2020; Dong et al., 2019).

Despite the promising findings of this study, we acknowledge here the limitation that the data collected, and subsequent analysis were somewhat limited due to the voluntary nature of teacher participation in this study. Teachers who participated were already inclined to consider, and were, at least, minimally interested in, CS instruction. However, we believe that the insights gained may still offer useful guidance for teacher education and future planning of online PD in elementary CS instruction.

Conclusion

Computer science is a rapidly emerging area in elementary teacher education, with elementary teachers being required to integrate and teach foundational computer science content regardless of how prepared they feel to do so (Hutchison et al., 2021, 2022). This research indicates the rich understandings that teacher perspectives have to offer on professional development in elementary computer science instruction situated in literacy. We consider that by studying and harnessing elementary teacher perceptions in this PD we, as teacher educators and researchers, might better prepare future teacher training in CS and in relevant literacy instruction. Moreover, we understand that this study involved a population of volunteer teachers who were self-motivated to learn more about computer science instruction for all learners. As we look to the future, we ask: "In the objective to support all students in elementary computer science learning, how might we develop beneficial PD to support all elementary teachers in computer science instruction?" It is in this question that we will frame future research and professional development in teacher education.

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