Diverse Approaches to School-wide Computational Thinking Integration at the Elementary Grades: A Cross-case Analysis

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ABSTRACT

Elementary schools throughout the United States are attempting to integrate computational thinking (CT) into their instruction, often without guidance from research about effective approaches for achieving particular CT goals. This cross-case study investigated the school-wide integration of CT in three elementary schools in a large urban school district in the Northeast that has a district-led CS for All initiative. Data included interviews with teachers, professional development providers, and school administrators as well as surveys from teachers and classroom observations in each participating school. Findings revealed three distinct approaches to integration: (a) single teacher leader-driven model, (b) scaffolded professional development model, and (c) intensive coaching model. These approaches reflect the visions set by administrators and teachers, methods used by professional development providers, and cultures of each school. Across the case studies, common pedagogical approaches included strategic use of both unplugged and plugged activities with a range of computational tools, a focus on collaborative project-based learning, and the use of CT-specific academic language to anchor new CT learning within the academic disciplines. The study highlighted advantages and challenges within each integration approach with implications for schools considering CT integration.

CCS CONCEPTS

• **Social and professional topics** → **K-12 education**; • **Applied computing** → **Education**;

KEYWORDS

Computational thinking, Integration, Case study, Elementary education

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1 INTRODUCTION

As computational thinking (CT) education is reaching the elementary grades, questions emerge regarding (1) how to add CT into an already full school day, (2) how to ensure that CT activities are developmentally appropriate, and (3) how to implement strategies to integrate CT into other content areas (e.g., [3]). Little research exists to guide elementary schools in addressing these questions. Schools, therefore, must make decisions based solely on professional judgement and experiences. The existing literature points towards challenges such as finding space for CT in the curriculum [3] and the need for significant teacher professional development (e.g., [8]) as well as benefits such as increased creative problem solving [5] and engagement in the disciplines [1]. Given the widespread focus on the inclusion of CT in the elementary grades, it is critical to document and critically examine how schools bring CT into their unique contexts. This study, therefore, investigated how three elementary schools integrated CT into their school settings.

2 RELATED WORK

2.1 Computational Thinking in the Elementary Grades

At the elementary grades, computer science (CS) is often introduced to students alongside the concept of CT. Although there is no consensus on a single definition of CT, there is some agreement that CT involves systematically approaching problem solving (e.g., algorithmically) in a manner that results in solutions that can be reusable in different contexts [13]. This definition of CT can be applied to problem solving both with and without computers and lends itself well to opportunities to integrate CT into the other disciplines. A primary goal, therefore, may be to create computational

experiences for young learners that allows them to experience CT in the context of the other disciplines. In this manner, CT might be designed as an “intersubjective experience” [12, p.29] The rationale for bringing CT into the early grades rests on the fact that computing is ubiquitous and that people who can successfully navigate and engage with computational technology in a productive, creative manner are at an advantage. Thus, from an equity perspective, offering early and sustained CT experiences to all learners, not just those who are born into privilege, is imperative [15]. However, although many researchers and practitioners advocate for including CT in elementary instruction, little practical guidance exists regarding how to do so [11].

2.2 Computational Thinking Integration

The push to integrate CT into the disciplines is gaining momentum (e.g., [6, 12, 15]). The central argument for the integration is the natural fit of CT into the disciplines, especially the science, technology, engineering, and mathematics (STEM) areas wherein the disciplinary instruction can be enhanced by applying the concepts and tools of computing and CT. Several efforts focus on developing CT integration frameworks to guide pedagogical practice. Sengupta and colleagues [12] proposed pedagogical guidelines for integrating CT in K-12 STEM, which emphasized re-conceptualizing CT as discursive, perspective, and embodied experiences. Another model includes three-levels of CT integration along a progression: (a) identifying CT concepts and practices existing in the curriculum, (b) enhancing the connections between disciplinary and CT concepts through additional lessons, and (c) extending disciplinary knowledge by integrating CT-related activities[14]. Existing studies suggest that computational experience can advance students’ understanding of disciplinary content, CT skills, and awareness about the role of computation across STEM fields [9]. This literature points towards a continuum of integration approaches, acknowledging that full integration is difficult to achieve [6]. In addition to these pedagogical frameworks, CT integration is also driven by practical considerations. For example, integration is often an answer to finding time for CT in an already busy school day [2] as well as lack of resources for stand-alone classes [17].

2.3 Purpose and Research Questions

As stated above, while pedagogical frameworks for CT integration exist, in-depth studies of CT integration approaches in elementary schools are scarce. Schools with access to resources and expertise, as well as the time and freedom to explore ways to integrate CT into instruction, are forging ahead on their own. Although professional experience and collaborative decision-making may result in effective and innovative ways of integrating CT, this “every school for itself” approach leaves no room for collective knowledge-building or sharing successes and challenges. Therefore, the purpose of this study was to explore and document how three elementary schools integrated CT into their curriculum. The research questions that guided this study included: 1. What school-wide approaches did each school take to integrating CT into its instructional context? and 2. What similarities and differences emerged among the schools in their approaches to CT integration?

Table 1: School Demographics

School	A	B	C
Number of Students	500	1597	1625
English Language Learners	33.8%	29.6%	31.4%
Students with Disabilities	20%	14%	20%
Low Income Households	84.6%	72%	83%
Teachers with 3+ Years Experiences	67%	83%	71%

3 METHODS

This study primarily used a qualitative cross-case methodological approach[10]. The main analytic method included inductive coding of interviews with teachers, professional development (PD) providers, and school administrators to gain an understanding of how the three schools integrated CT into their specific contexts. This study also utilized structured classroom observations and teacher surveys as additional data sources for triangulating findings obtained through the interviews. Thus, the quantitative data was secondary to the qualitative data. Given the qualitative nature of this study, careful attention was given to trustworthiness and credibility through processes such as triangulation of interview data sources across teachers, PD providers, and administrators and conducting member checking procedures with participants that included sharing findings and reports with them and then meeting with participants to discuss trends in the data, ask clarifying questions, and seeking feedback.

3.1 Participants

This study took place in three elementary schools in a large urban school district in the Northeast. While the district has a CS for All initiative, this study was part of a foundation-funded CT integration initiative. The study began in 2017 and is ongoing. Data presented in this paper reflect two years of implementation within all three schools. Table 1 provides demographic information for each school. Participant selection was based on grade level and content area focus. Each school had a different level of implementation so the number of interview participants varied. School A had one primary teacher implementing CT across all grades (n=1). School B had CT integration in two grade levels, so two teachers per grade level were interviewed (n=4). School C had implementation across all grade levels so one teacher per grade level was interviewed (n=6). The administrators (n=3) and PD providers (n=3) were all also interviewed. Surveys were sent to all of teachers in the grade levels that participated in CT integration at each school and resulted in 44 teacher respondents. Other teachers in the schools also had access to the PD and resources, but were not included in data collection.

3.2 Surveys

Pre and post surveys were administered online to all teachers in each school that participated in the CT initiative and consented

to participate in the research. Across the three schools, a total of 44 teachers completed the pre-survey and 38 teachers completed the post-survey. The surveys were developed through a collaborative process involving university faculty, research scientists, and practitioners, and included items from validated surveys about CT integration [18]. This survey was chosen as it had undergone extensive refinement and use across a large school district. The survey asked teachers to reflect on their level of comfort in implementing and understanding of CT integrated activities within their curricula. The survey also asked teachers to reflect on perceived challenges and supports in their integration efforts.

3.3 Observations

Researchers conducted structured observations of CT integration in all three schools that participated in the initiative. Our observation instrument had elements that allow for quantitative and qualitative data collection. The researchers collected quantitative data about the classroom instruction adapted from an existing instrument called the Collaborative Computing Observation Instrument [7] for use for classroom observations instead of through video analysis. The instrument also allowed for collection of field notes on the specific activities taking place in the classroom. We conducted two observations of CT integration for each teacher who was interviewed.

3.4 Interviews

Semi-structured interview protocols were developed and used to guide interviews with participants across the three schools. These interviews were developed through a collaborative process involving university faculty, research scientists, and practitioners and were piloted the previous year. Interviews were audio recorded and transcribed. The teacher interviews asked participants to describe any prior experience with CT, how they envisioned CT integration looking within their curricula, and examples of CT integrated lessons they implemented. The administrator interview asked participants to share their vision and plans for achieving school-wide integration. The PD provider interview asked participants to describe their approach and yearly plan for educating and supporting teachers with integration. Data analysis involved an inductive approach using a constant comparative technique [4] using the Dedoose software, a collaborative, online qualitative analysis tool. This process resulted in a structured coding scheme that was revised as additional interview data were analyzed.

3.5 Cross-Case Analysis

Each school was treated as a distinct case. After initial individual case development, a cross case analysis was conducted, focusing on similarities and differences between the CT implementation approaches. Thus, the cross-case analysis process provided a lens into both the unique and collective experiences related to school-wide CT integration.

4 RESULTS

4.1 Case Model A: STEM Teacher as CT Integration Lead

4.1.1 Implementation Drivers. In Case Model A, the primary driver for CT integration was one teacher who worked closely with a PD provider to develop CT-integrated lessons and to run PD sessions at her school. This teacher was the science, technology, engineering, and mathematics (STEM) teacher for the school. The main content focus of CT integration for this teacher was science. Since this teacher taught all of the students in the school, all students were exposed to CT. Although other teachers in the school participated in PD and made some efforts to implement CT in their classes, without the involvement of this one teacher, CT integration would not have been school-wide. The school administration supported CT integration by allowing for planning time, but the teachers could not use existing grade-level meetings for this planning. The vision for CT integration came from the STEM teacher rather than the principal.

4.1.2 Professional Development Approach. The PD provider focused on helping teachers understand the theoretical components of CT and encouraged them to construct their own definition of CT and their own CT lessons. Rather than starting with a clear definition of CT and lessons for them to try out, the PD provider designed opportunities for teachers to develop their own understanding and supported the teachers in developing their own integrated lessons. The STEM teacher explained this approach had advantages and disadvantages. The teachers enjoyed the articles about CT that the PD providers gave the teachers, which had useful information, but they also wanted to spend more time focused on practical applications. She explained, “The PD providers would send out articles prior to the [PD] and some people really gravitated towards that...So maybe we all come in and work on the practical aspect of abstraction, but then you. ...[can] stay a little bit later and go over the articles, if you want that more theoretical side.”

This PD model also included classroom intervisitation, where teachers would observe other teachers implement CT lessons. However, this proved difficult to organize since few teachers were able to leave their classes, and few, other than the STEM teacher, were able to create their own CT lessons. In the second year, the PD approach shifted from a primarily theoretical one to one that alternated between the theory of CT integration and practical, hands-on PD sessions.

4.2 Case Model B: Professional Development Scaffolded Model

4.2.1 Implementation Drivers. In case model B, the school administrators were the drivers of the initiative. The PD providers and administrators worked together to develop the PD approach, in which teachers developed CT understanding by directly learning from and observing CT integration by the PD providers. The PD providers and teachers worked together to identify and develop CT integrated lessons. Additionally, in the second year, the administration designated an in-school coach to work with the teachers new to CT integration. This coach was a teacher who participated in the first year.

4.2.2 Professional Development Approach. The focus of PD was on aligning CT with existing math and English language arts (ELA) lesson plans through scaffolding plugged (i.e., computer-based) and unplugged (i.e., non-computer based) activities. The PD providers used a “I do, we do, you do” model, in which they first modeled CT lessons in the classroom themselves, then co-taught lessons with teachers, and finally observed lessons that the teachers created and implemented independently and provided feedback. The PD provider explained, “I do” or the beginning portion of the coaching...so actually going into the school and lesson modeling the curriculum and the teachers are observing. And we’ll have like [production] resources to kind of reflect on that activity. Then we do a regional approach where we’re coaching an activity together, and then kind of the final part which will take place towards the tail end of the school year is the ‘you do,’ where we, as the coaches, are doing the observations and the teacher has designed and implemented the curriculum”. CT integration planning and PD occurred during existing planning meeting times, thus not creating additional demands on teachers’ time. Lastly, the PD providers helped the school gradually build a vision of implementations among the administrators and teachers.

4.3 Case Model C: Whole-school CT Embedded Coaching Model

4.3.1 Implementation Drivers. Of the models, Model C was the most resource and personnel intensive. In this model, the PD provider spent three days a week in the school as an embedded coach. This school also had the most robust infrastructure for CT integration, as the school-based coaches and administrators all worked with the PD provider to develop CT integrated curriculum and lesson activities. The school administrator explained, “Honestly, I think the best support we have had is having the PD provider here in the school with us, you know, three to four days a week...So having someone knowledgeable, somebody who’s able to coach and give great professional development, that has been the most helpful.” After the first year of integration, the school created a CT leadership team that included administrators, school-based coaches, teachers and the PD provider.

4.3.2 Professional Development Approach. The PD providers initially focused on the use of CT academic language and helping teachers recognize how they are already using CT concepts in their ELA and math instruction (e.g., sequencing a story in the correct order). As teachers gained proficiency with CT, additional activities such as unplugged CT activities were introduced by the PD provider. Thus, there was a scaffolded approach to slowly familiarize teachers with the CT concepts and how they might be more explicitly called out and addressed within the curriculum. The PD provider explained, “It’s the engage, explore, reflect kind of model too. Engage in the new content. Let’s explore it together with an activity, and then reflect on that activity.” Like Case Model B, integration primarily focused on ELA and math. However, the PD providers worked with the teachers on two approaches to CT integration. The first approach included the integration of CT into existing school-wide collaborative learning activities that took place twice a month. The other approach involved CT integration into regular classroom instruction in the grade levels of focus. Depending on different

grade levels, there was a different emphasis on CT integration. For example, one teacher focused on teaching decomposition in grades K-3, and abstraction in grades 4-6.

4.4 Cross Case Analysis

4.4.1 Starting Places for CT Integration. Across all the schools, CT integration had to start by helping teachers with little or no experience with CT feel confident in their ability to use CT in their teaching, and understand the pedagogical alignment of CT into the content areas. Although the schools addressed these areas in different ways, several commonalities emerged. First, all of the schools began the initiative with models that they believed would result in school-wide CT integration. Differences in the kind and level of administrative vision and support had implications for how widely CT was implemented among the faculty. For example, in Case Model A, the vision for the model came from a teacher rather than an administrator, and there was a change in administrators during the initiative. This change resulted in less explicit emphasis on CT in the school as a whole. Thus, although all the teachers had access to PD and could implement CT, the main implementer was one teacher who was personally invested in CT integration. However, because that teacher taught all of the students, the school still had school-wide CT integration at the student level, if not at the teacher level.

Second, in all three schools, the PD providers introduced CT by showing teachers how they were already using many CT practices in their normal instruction in the content areas they teach. In Case Model B, for example, the PD providers worked with teachers to identify within their existing lessons those places where they engaged in decomposition, algorithms, sequencing and abstraction, which helped them understand and contextualize these new concepts and feel confident using the vocabulary with their students. Lastly, when examining the PD approaches, the most effective way of introducing CT into instruction for teachers new to CT appeared to be with existing lessons that were already developed and that aligned with current practices and standards, rather than relying on teachers to develop their own integrated lessons. For example, in Case Model C, the school already had established school-wide math and ELA collaborative project-based learning activities before they began the initiative. The PD providers worked with the math and ELA coaches to take these lessons and integrate CT into them prior to presenting the lessons to the teachers. In that way, teachers could try out this new practice using developed materials within an activity structure that they were already familiar. Thus, CT was integrated into an existing structure, using lessons that the PD providers created in conjunction with school-based literacy and math coaches.

4.4.2 Teachers’ Definitions of CT. Across these case models, the teachers generally defined CT as two related approaches to problem solving: (1) a general ability to think systematically or algorithmically and (2) a metacognitive process for thinking more strategically about one’s own problem solving approach (see Figure 1). In several cases, these two approaches to problem solving were described together rather than as two different definitions of CT. For example, one teacher in Case Model C explained, “I feel that CT is just a

Figure 1: Teacher's definitions

way to allow our students to think more critically, a way that students can engage with the meta-cognition that goes with thinking through a task." In Case model A, the teacher expressed that she struggled to come up with her own definition of CT, but she still defined CT as problem solving in a similar manner to the teachers' definitions in Case models B and C. She explained:

"That's something that's been challenging... but also helpful as I work through trying to determine my own definition of what computational thinking is...it seems like a way of thinking that involves analyzing a situation, coming up with creative ways to problem solve, using abstraction and modeling, to be able to come up with multiple solutions that either a person or computer would be able to solve."

Survey data confirmed teacher interviews with 83% of the teachers agreeing or strongly agreeing with the statement that computational thinking involves logically solving problems. Although there was consensus about CT as problem solving, there was less agreement regarding the need for computers as part of CT with 36% of the teachers stating that CT involves using computers to solve problems.

4.4.3 Instructional Approaches to CT Integration. Among the schools, six basic instructional strategies were used in integrated CT instruction with three predominant approaches: Use of CT academic language, project-based learning, and use of computational thinking-specific tools (see Figures 2, 3, and 4). The teachers explained that using CT academic language helped reinforce those concepts and anchored new CT constructs to activities that the students were already doing. For example, they would refer to solving a difficult problem as "debugging" and discussed the plot of a story as a "sequence" of events. One of the teachers in Case Model C explained the emphasis on using CT academic language and encouraging the students to use that language with each other, "You would hear [student] discussions and they're having and you would hear them using the CT language...they were able to go back and say, 'Oh, no, that's an algorithm' or 'no, we use logic to solve this, so let's evaluate this.'" Similarly, a teacher in Case Model B stated, "I hear it

in their conversations and it's becoming more and more natural to them."

Figure 2: Pedagogical Approaches Described in School A

Figure 3: Pedagogical Approaches Described in School B

Figure 4: Pedagogical Approaches Described in School C

The teachers across the school settings focused on both unplugged activities and the use of plugged activities with computational tools such as Scratch or robotics. The percentage of unplugged to plugged activities, however, varied among the schools. Interestingly, the STEM teacher in Case Model A reflected that she thought that among all the lessons, the unplugged activities were the most successful for integrating CT into science instruction. Teachers in Case Model B had the highest proportion of plugged activities compared to the other case models, however, they acknowledged the importance of unplugged activities. One teacher reflected, "The [PD provider] showed us a lot of unplugged activities so that the plugged activities make sense for the kids. So I'll do

more the unplugged stuff so that [the students] can do the plugged activities.”

Lastly, both Model A and C schools used on collaborative project-based learning (PBL), although teachers in Model C referred to this work as “collaborative student work” while the STEM teacher in Model A referred to this as PBL. The scale of these PBL activities, however, was different between the schools. In Model A, the STEM teacher created PBL activities that would fit within existing science classroom instruction. The STEM teacher explained that she was leveraging computational tools such as simulations alongside CT practices such as using flow charts to help students systematically answer questions related to questions that in the past seemed overly abstract to the students. She explained,

“Right now, we’re working with the food chain and we’re looking at what happens if one animal increases and one animal decreases. I always dreaded that lesson. It’s very hard to get them to understand those relationships. Now, they’re picking up on it in such different way and they’re starting to create their own flowcharts. They self-create these tools!”

In Model C, there was already an infrastructure for school-wide collaborative PBL wherein CT could fit. These were dedicated times when all the students in the school engaged in solving either a math or ELA task collaboratively. During these times, the teachers worked on skills such as perseverance, use of CT academic language, and general collaboration within activities that integrate CT into core-content areas.

4.4.4 Advantages and Disadvantages of the Case Models. These three CT integration case models reflect decisions made by the schools based on their unique contexts. The purpose of this paper was not to ascertain which model was “better” than the others. Rather, this study unpacked the CT integration approaches used within these three schools for the purpose of providing details that schools interested in CT integration can examine to see which aspects of the three case models could address the CT integration goals that they establish as well as resources available to them. Table provides a summary of advantages and challenges of each case model.

5 CONCLUSIONS

Each case model presents a lens into different approaches to CT integration under different conditions, illustrating a continuum of implementation approaches described in the literature (e.g., [6]). This continuum ranged from Case Model A, where one teacher drove the entire integration process, to Case Model C, where the school had a great deal of resources including an embedded coach. Case Model A is a likely scenario in smaller schools or those that do not have a great deal of CS resources whereas Case Models B and C are more likely in larger school districts or those with robust CS for All initiatives. The teachers adopted a broad definition of CT as problem solving strategies, which is consistent with definitions of CT that state that problem solving approaches related to CT are derived from computer science but applicable across multiple domains [13] [16]. Overall, each case had affordances and challenges and reflected instructional and administrative decisions that were unique to those specific school contexts. Thus, CT integration did not look the same across the schools.

Table 2: Advantages and Challenges of CT Integration within each Case Model

Case	Advantages	Challenges
Case A	<ul style="list-style-type: none"> -All students receive CT instruction from the STEM teacher throughout the year. -CT lessons could be implemented, iterated upon, and refined over multiple class sessions. -The STEM teacher can model CT integration to classroom teachers in the classrooms that she instructs (if the classroom teachers are present). 	<ul style="list-style-type: none"> -If the lead teacher leaves, the CT integration may not be sustained. -The teacher who led the initiative had control of her own instruction but had no authority to make school-wide changes in instructional focus. -PD focused on understanding CT conceptually prior to an applied manner, which can create barriers for teachers who want immediate lessons to implement.
Case B	<ul style="list-style-type: none"> -Teachers saw CT implementation modeled by the PD providers from the beginning and then slowly took on ownership of CT integration in a scaffolded manner. -CT integration strategy leveraged existing lesson planning times and structures rather than requiring additional time from teachers for planning. -The focus on math and ELA addressed disciplinary priorities. 	<ul style="list-style-type: none"> -Because only a few grade levels received PD each year, there was inconsistent implementation throughout the year. -Teachers who received PD in year 1 did not receive the same level of support the following year as new grade levels were added into the CT integration initiative.
Case C	<ul style="list-style-type: none"> -Whole school implementation included administrators, teacher leaders, and classroom teachers. -The school-embedded CT coach could be responsive to teacher needs consistently throughout the year. -Initial focus on CT academic language and unplugged activities was a smooth on-ramp for teachers to gradually learn about CT prior to using technology tools used in plugged activities. -The focus on math and ELA addressed disciplinary priorities. 	<ul style="list-style-type: none"> -The resource and staff intensity of this model would make it difficult to implement in schools with fewer personnel and content area expertise. -The school-wide implementation created a resource scarcity as classrooms required more computers and technology than was available in the school.

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REFERENCES

- [1] Laura Benton, Piers Saunders, Ivan Kalas, Celia Hoyles, and Richard Noss. 2018. Designing for learning mathematics through programming: A case study of pupils engaging with place value. *International journal of child-computer interaction* 16 (2018), 68–76.
- [2] Danielle Cadieux Boulden, Eric Wiebe, Bitu Akram, Osman Aksit, Philip Sheridan Buffum, Bradford Mott, Kristy Elizabeth Boyer, and James Lester. 2018. Computational Thinking Integration into Middle Grades Science Classrooms: Strategies for Meeting the Challenges. *Middle Grades Review* 4, 3 (2018), n3.
- [3] Krista Francis and Brent Davis. 2018. Coding robots as a source of instantiations for arithmetic. *Digital Experiences in Mathematics Education* 4, 2-3 (2018), 71–86.
- [4] B Glaser and A Strauss. 1967. The discovery of grounded theory Aldine Publishing Company. *Hawthorne, NY* (1967).
- [5] Paulina Haduong and Karen Brennan. 2019. Helping K–12 Teachers Get Unstuck with Scratch: The Design of an Online Professional Learning Experience. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*. 1095–1101.
- [6] Maya Israel and Todd Lash. 2020. From classroom lessons to exploratory learning progressions: mathematics+ computational thinking. *Interactive Learning Environments* 28, 3 (2020), 362–382.
- [7] Maya Israel, Quentin M Wherfel, Saadeddine Shehab, Evan A Ramos, Adam Metzger, and George C Reese. 2016. Assessing collaborative computing: development of the Collaborative-Computing Observation Instrument (C-COI). *Computer Science Education* 26, 2-3 (2016), 208–233.
- [8] Diane Jass Ketelhut, Kelly Mills, Emily Hestness, Lautaro Cabrera, Jandelyn Plane, and J Randy McGinnis. 2020. Teacher change following a professional development experience in integrating computational thinking into elementary science. *Journal of Science Education and Technology* 29, 1 (2020), 174–188.
- [9] Irene Lee, Shuchi Grover, Fred Martin, Sarita Pillai, and Joyce Malyn-Smith. 2020. Computational Thinking from a Disciplinary Perspective: Integrating Computational Thinking in K-12 Science, Technology, Engineering, and Mathematics Education. *Journal of Science Education and Technology* 29, 1 (2020), 1–8.
- [10] Sharan B Merriam. 1998. *Qualitative Research and Case Study Applications in Education. Revised and Expanded from "Case Study Research in Education."*. ERIC.
- [11] Phil Sands, Aman Yadav, and Jon Good. 2018. Computational thinking in K-12: In-service teacher perceptions of computational thinking. In *Computational thinking in the STEM disciplines*. Springer, 151–164.
- [12] Pratim Sengupta, Amanda Dickes, and Amy Farris. 2018. Toward a phenomenology of computational thinking in STEM education. In *Computational thinking in the STEM disciplines*. Springer, 49–72.
- [13] Valerie J Shute, Chen Sun, and Jodi Asbell-Clarke. 2017. Demystifying computational thinking. *Educational Research Review* 22 (2017), 142–158.
- [14] Kevin P Waterman, Lynn Goldsmith, and Marian Pasquale. 2020. Integrating computational thinking into elementary science curriculum: An examination of activities that support students' computational thinking in the service of disciplinary learning. *Journal of Science Education and Technology* 29, 1 (2020), 53–64.
- [15] David Weintrop, Margaret Walton, Andrew Elby, Janet Walkoe, et al. 2020. Mutually Supportive Mathematics and Computational Thinking in a Fourth-Grade Classroom. (2020).
- [16] Aman Yadav, Sarah Gretter, Jon Good, and Tamika McLean. 2017. Computational thinking in teacher education. In *Emerging research, practice, and policy on computational thinking*. Springer, 205–220.
- [17] Aman Yadav, Hai Hong, and Chris Stephenson. 2016. Computational thinking for all: pedagogical approaches to embedding 21st century problem solving in K-12 classrooms. *TechTrends* 60, 6 (2016), 565–568.
- [18] Aman Yadav, Chris Mayfield, Ninger Zhou, Susanne Hambrusch, and John T Korb. 2014. Computational thinking in elementary and secondary teacher education. *ACM Transactions on Computing Education (TOCE)* 14, 1 (2014), 1–16.