How do Preservice Teachers Learn to Teach Integrated Computational Thinking?: Evidence from Planning, Enactment, and Reflection

RESEARCH

RACHAEL DEKTOR
SAMUEL SEVERANCE
KIP TÉLLEZ

*Author affiliations can be found in the back matter of this article

ABSTRACT

This study examines pre-service teachers' (PSTs) beliefs and understandings about computational thinking (CT) integration and lesson implementation over time. Utilizing a design-based research approach, 3 PSTs led the co-design of integrated CT lessons with support from researchers and enacted these CT integrated lessons with K-5 students. All PSTs participated in a whole-group CT workshop and engaged in one-on-one lesson design sessions with a researcher. We utilized a grounded theory approach to qualitatively analyze pre-surveys, semi-structured interviews, and video data of three PSTs enacting their lessons. We found that PSTs' initial beliefs about CT instruction – including the importance of it – were reinforced through their participation in our lesson design and implementation process. We also saw PSTs developed deeper understandings and more nuanced beliefs about the importance of CT integration and supporting multilingual learners (MLs) with English language development (ELD) strategies. PSTs also developed beliefs about what CT integration should look like and how it should be taught. This multiple case study demonstrates how providing rich design opportunities for PSTs to engage in CT integration work can support the productive development of PSTs beliefs about CT integration and their capacity for CT lesson design.

CORRESPONDING AUTHOR:
Rachael Dektor
University of California, Santa Cruz, United States
rdektor@ucsc.edu

KEYWORDS:
Computational thinking; computational thinking integration; preservice teacher education; computer science education

TO CITE THIS ARTICLE:
Dektor, R., Severance, S., & Téllez, K. (2024). How do Preservice Teachers Learn to Teach Integrated Computational Thinking?: Evidence from Planning, Enactment, and Reflection. *Journal of Computer Science Integration,* 7(1): 2, pp. 1–16. DOI: https://doi.org/10.26716/jcsi.2024.06.27.54

INTRODUCTION: CHALLENGES AND OPPORTUNITIES IN INTEGRATING COMPUTATIONAL THINKING INTO PRE-SERVICE TEACHER EDUCATION

CHALLENGES IN PRESERVICE TEACHER EDUCATION

If preservice teacher education has any transformative potential, then it is largely up to teacher educators to engage their candidates in novel curricula and pedagogy not yet found in schools. In making this point, we are not suggesting that what preservice teachers (PSTs) learn in their practicum is never transformational. Certainly, many cooperating/mentor teachers engage in pedagogies designed to increase student engagement, achievement, or equity that genuinely alters schooling. However, contemporary schools have been characterized as a conserving force, reproducing in children and youth the knowledge, values, and economy of their parents or even grandparents. This failure at transformation yields, among other consequences, a reproduction of the existing and unacceptable social inequities (Ritzman & Tomaskovic-Devey, 1992). On the other hand, some research has suggested that the transformative hopes of the university-based, professional program are "inert" or "washed out" by beginning teaching experience (Korthagen et al., 2001). This finding may suggest that teacher educators abandon any transformational hopes and instead prepare PSTs to teach exactly what is being taught in the schools where they are learning to teach.

This tension is as old as formal teacher education itself. The most recent iteration is mired in a mostly symbolic debate between those who promote a "practice-based" teacher education (Janssen et al., 2015) and those who suggest that this emphasis ignores important questions about race, power, and Whiteness, for example (Daniels & Varghese, 2020). In place of debates, teacher educators need concrete examples of changed practices that show promise for future implementation. We argue that providing rich design opportunities for PSTs to engage in computational thinking (CT) design work can draw on PSTs' existing beliefs about work to strengthen and develop those beliefs. Existing research highlights the importance of focusing on beliefs because they can be powerful predictors of actions (Pajares, 1992). Therefore, providing PSTs with learning opportunities that allow for participation in social processes (Mead, 1934) that can strengthen and develop PSTs' beliefs about the importance of teaching CT and their own self-efficacy beliefs can have a powerful influence on PSTs' instructional choices when they enter the workforce.

In this study, we examine how a university-based teacher education program working in close partnership with a local school district can serve as a transformative context by helping PSTs to engage in integrating computational thinking (CT) into district content curricula. This approach not only has the potential to build the capacity of these future teachers to design CT experiences, but also immediately supports the district's larger aim of having all students engage in CT, including multilingual learners (MLs), a group woefully underrepresented in the computing fields (Martin et al., 2015). Using interviews, lesson videos, and other artifacts, our study documents what three PSTs believed about their capacities for teaching integrated CT to multilingual learners and how those beliefs changed. Creating design opportunities that leverage and extend PSTs' beliefs can function as a transformative experience for PST learning. This study highlights that this type of design work and learning experience can develop PSTs beliefs about the importance of providing CT education to students, beliefs about their own ability to teach CT, and beliefs about supporting MLs.

CHALLENGES IN COMPUTER SCIENCE AND COMPUTATIONAL THINKING EDUCATION

CS is "the study of how technology and computing systems are created and their impact on society" (California State Board of Education, 2018, p. 1). The field of CS is rooted in theory and practice informing how people engage technology in problem-solving, with an emphasis on the creation of tools (California State Board of Education, 2018). Engaging in CS necessitates the use of CT. CT is a set of skills and practices that computer scientists rely on to define and solve problems which can ultimately be carried out by a computer (Grover & Pea, 2013). While CT is central to CS, the skills and practices are applicable to other content areas (e.g., CT is one of the Science and Engineering practices in the Next Generation Science Standards (NGSS Lead States, 2013). Therefore, learners can develop foundational CT skills and practices by engaging with CT in contexts other than CS (Grover & Pea, 2013; 2018; Yadav et al., 2016). Our study focuses specifically on CT integration because of the promises an integration approach to teaching CT can work to alleviate barriers to CS education implementation (Wang et al., 2016; Israel et al., 2021).

Many communities remain underrepresented in the field of CS (Google/Gallup, 2016), despite policy reforms that promote inclusive CS education (e.g., ACM et al., 2016), and a widespread recognition of the importance that learners have opportunities to engage with CS (NASEM, 2018; Wang et al., 2016). Creating meaningful opportunities for learners, particularly underrepresented learners, to participate in CS remains a pressing issue (NASEM, 2021; Wilson et al, 2010).

Addressing the systemic barriers in teacher preparation, curriculum design, and implementation is crucial for enhancing the capacity of K-12 school systems to engage students in meaningful CS learning. Research-practice partnerships (RPPs; Coburn & Penuel, 2016; Sato & Loewen, 2022) that focus on design work offer promise in overcoming challenges to innovation within school systems by developing system-level interventions tailored to districts' needs. The work in this paper explores a curriculum collaborative design (co-design) project within a RPP in the western United States. The project's goal is to create equitable learning opportunities in CS, with an emphasis on CT, for K-8 students, particularly multilingual students from Latine backgrounds.

PROMISING DESIGN-BASED RESEARCH APPROACHES

Researchers have explored integrating CT into content areas, other than CS, to support the development of learners' understanding of CT, providing learners with experiences that will build their capacity to do computer science (Century et al., 2020; Harlow et al., 2018; Kafai et al., 1997; Klopfer et al., 2005; Pozos et al., 2022; Welch et al., 2022). Current research suggests that student participation in CT-integrated lessons increase their learning about CT (Weintrop et al., 2021; Arastoopour Irgens et al., 2020). Additionally, supporting teachers with integrating CT into content areas they already teach can work to alleviate barriers to CT implementation, such as a lack of teachers prepared to teach CS and the prioritization of other academic goals (Wang et al., 2016; Israel et al., 2021, Coenraad et al., 2021). Coenraad et al. (2021) found that more than 80% of the preservice and inservice teachers who participated in a professional development focused on integrating CT into elementary science lessons were able to successfully integrate CT into their lessons, to varying degrees. Other studies, focusing on student learning, demonstrate that a content area can serve as a valuable context for engaging in CT practices and skills. For example, Weintrop et al. (2021) examine student engagement with a CT integrated math curriculum and highlight how CT enhanced students' math learning, while math provided the context for students to engage with CT skills and practices in a meaningful way. Arastoopour Irgens et al. (2020) measured high school students' use of CT practices before and after engaging in a CT integrated science unit. Their results demonstrated that students' use of CT practices increased between the pre and post test. These results offer promising outcomes related to CT integrated instruction.

Engaging PSTs in co-design (Penuel, 2019; Severance et al., 2016)- where practitioners and researchers work together and pool their expertise to develop learning opportunities-operated as a way to engage PSTs in a rich task (i.e., designing CT lessons) while overcoming limited resources and instructional time. Engaging PSTs in co-design work to develop materials for actual classrooms functioned to bring CT learning to students who would not otherwise have access to it given various constraints (e.g., CT not currently in official district curriculum). This integration takes place within existing subjects, such as science and math, over an extended period of time, rather than in separate computer science classes. Prior work suggests the promise of training student teachers (PSTs) in CT and engaging them in co-design work, particularly in relation to shaping their beliefs about CT instruction (Yadav et al., 2017).

RESEARCH QUESTIONS

This paper examines the beliefs of a cohort of PSTs who volunteered to co-design with researchers and implement CT-integrated lessons and asks:

(RQ1) How did student teachers' beliefs about integrated CT instruction change over time?

(RQ2) What aspects of the design space facilitated student teachers' shift in beliefs and their engagement in productive CT integrated lesson design?

THEORETICAL FRAMEWORK

Drawing primarily on a symbolic interactionist perspective (Mead, 1934), we conceptualize beliefs as a cognitive process largely based on experiences which occur socially or externally. The formation of beliefs is, generally speaking, the ideas and opinions a person forms based on the external world or evidence. Their beliefs are not formed in a vacuum, but can be influenced by other people as well as by participating in social processes, communities, and groups (Loeb, 1990; Hume, 2007; Miller, 1973). Therefore, teachers – including novice teachers like PSTs – will likely have beliefs both based on their own experiences as a student, the testimony of their teachers, the beliefs articulated to them by figures of authority, and through day to day interactions and attempts to solve problems (Pajares, 1992; Mead 1934; Miller, 1973). Mead developed what is now called symbolic interactionism, a theory in which beliefs are formed in participation in social processes (Biesta & Tröhler, 2016). The theoretical background informing this study is grounded in Mead's belief theory because he attends to the social practices which can contribute to belief development and change (Miller, 1973).

Mead's account of the development of beliefs involves mental faculties as well as relying on the world which exists externally from the mind. Mead emphasizes human's participation in social processes and interactions by positioning the development of consciousness and rationality as dependent on society and social interactions. According to this stance, PSTs' participation in social activities such as student teaching or collaborative design serve as opportunities for PSTs to engage in social processes and the world which exists outside of them and make meaning of those interactions which, in turn, shapes belief development (Miller, 1973; Mead, 1934).

Mead's (1934) theory about belief formation provides insight into the ways beliefs are developed through experiences and participation in social processes which inform the beliefs teachers hold when they enter the classroom as well as the continuous development of beliefs through participation in new experiences. Therefore, ongoing experiences in the classroom and participation in professional learning opportunities can continue to shape beliefs (Enderle et al., 2014).

METHODS

This study is a multiple case study, using multiple cases to explore a single phenomenon (Creswell, 2007). In order to recruit PSTs, we offered the opportunity to participate to all multiple subject teacher candidates (i.e., future elementary teachers), prioritizing PSTs placed in the partner district. Four participants in the partner district volunteered to engage in the co-design of CT lessons for their placement classroom, supporting a larger effort in the district and research-practice partnership focused on promoting CS education. One participant withdrew due to competing commitments. Three participants ultimately completed all of the participation requirements and were paid $500. Those three PSTs participated in lesson integration and implementation work, meeting with a researcher to co-design lessons and receiving various levels of support from their mentor teacher (Table 1).

PSTs participated in a 3-hour workshop facilitated by researchers. During this workshop they were introduced to computational thinking, design ideas, and tools. PSTs were also introduced to the notion of "coherence" in learning, which is a progression where learning builds and becomes more complex over time (Fortus & Krajcik, 2012; Reiser et al., 2021). This was done by having PSTs analyze CT lessons across a primary grade science unit to recognize how CT learning built incrementally over time. After the workshop, PSTs worked with their mentor teacher to identify lessons they would integrate CT into and then met with a researcher to co-design the lessons. While the PSTs took the lead of crafting the lessons, the researcher offered key ideas, critical suggestions, and instructional tools to support PSTs lesson design work (Figure 1).

Computational Thinking: The sort of thinking a computer scientist would use to solve a problem

DIFFERENT ASPECTS OF COMPUTATIONAL THINKING	EVERYDAY EXAMPLES
Problem Decomposition Breaking down a problem into more manageable sub-problems	• Getting ready for school • Writing parts of a story
Algorithms Precise step-by-step instructions for a solution	• Following a recipe • Finding perimeter of rectangle
Conditional Logic The use of logic to reach a conclusion about a problem (using IF...THEN statements)	• IF I don't understand a word, THEN I sound it out • IF the sun goes down, THEN it gets colder
Pattern Recognition Identifying something that repeats to help solve a problem	• Days of the week repeat • Life cycle of butterfly
Testing & Debugging The detection and fixing of flaws or inefficiencies in an approach	• Cooking, season to taste • Fixing flashlight that won't turn on
Abstraction The hiding of complexity to create simpler representations	• Human heart shown as a ♥ • United States of America → USA
Computational Artifact A tool that can take an input and give a useful output	• Flowchart for deciding what can be recycled • Rubric to provide feedback

Figure 1 Handout designed to support PST learning.

Before participating in the CT workshop, PSTs completed a pre-survey responding to open-ended questions such as, "What experiences have you had with computer science or computational thinking?" and "What do you think it should look like to have students use and learn about 'computational thinking' in your classroom?." After co-designing with researchers and enacting their lessons, PSTs submitted written lesson plans along with video recordings of their lessons with elementary students and also participated in a semi-structured interview. Mirroring key topics in the pre-survey, each semi-structured interview lasted 30–45 minutes and PSTs reflected on their reasons for joining the project, the lesson planning process, and how their lessons went when they taught them to their students. The interview protocol included questions such as, "How would you explain what 'computational thinking' is to someone not familiar with it?", "Describe the lessons your students engaged in that integrated CS or computational thinking", What proved helpful in planning your lessons? How so?", and "What, if any, English language development (ELD) strategies did you use during your lessons?."

In terms of data analysis, researchers transcribed the interviews and workshop audio using an online transcription service and then manually cleaned the transcripts. Researchers then coded transcripts from the initial workshop, semi-structured interviews and pre-survey responses for each participant.The coding process followed the constant comparative method derived from grounded theory (Charmaz, 2002). The coding process happened in two stages, with memo writing occurring throughout the entire process. The first stage of coding was initial coding. Each transcript was combed through and coded based on what stood out in the transcript. These descriptive codes covered small excerpts of text and led into the next stage of focused coding. Focused coding entailed small initial codes being collapsed into larger, more general codes that cover larger text excerpts (Charmaz, 2002). Memo writing served as a method to compare beliefs across all PSTs. Researchers also did rounds of deductive coding, using our theoretical framework on symbolic interactionism acting as an interpretive lens, where transcripts were coded with the specific purpose of gaining insights into our research questions (Wengraf, 2001). Codes were also applied to the video recordings and lesson plans and made clear how PSTs' reported beliefs were evident in their enactment of lessons.

Examples of codes include aspects of CT ("algorithms", "conditional logic") as well as coding for supports identified by PSTs ("cooperating teacher", "positive support"). Two researchers used a set of the codes and Dedoose's interrater reliability test to receive a pooled kappa score of 0.85. This score demonstrates a high consistency of our code application across multiple excerpts (De Vries et al., 2008). Analytic memos served as a tool throughout the data analysis process to identify key data for further analysis. Data was triangulated across all of the data sources before researchers engaged in co-reconstruction of meaning. The interview transcripts, workshop transcript, and pre-survey responses provide insight into PSTs' beliefs about what CT is, what CT integration looks like, and whether and how they ensured their multilingual learners can access the materials. The lesson recordings and lesson plans are data sources that provide further insight into PSTs beliefs by allowing researchers to triangulate between PSTs' reported beliefs and what they actually did in the classroom.

RESULTS

We found that PSTs believed in the importance of CS/CT education for their students prior to participating, and after designing and implementing lessons, PSTs' beliefs about the importance of CT/CS education were reinforced. They believed they were able to teach CS/CT to their students, and believed that it was something they would continue to implement as new teachers in the workforce. The positive experiences of teaching lessons that integrate CT are instances of PSTs taking on the role of a teacher who is capable of teaching CT and participating in the processes and activities central to that kind of work. According to Mead, participation and engaging in certain roles is essential to the development of the mind, and ultimately beliefs (Mead, 1934).

In each case, we found that (1) PSTs' beliefs about what constitutes CT integration developed over time to include multiple CT aspects, intentional ELD instruction,

PST	GRADE	LESSON TOPIC	PRIMARY CT TOPIC
Andrew	3rd Grade	Math: Fractions	Conditional logic
Sarah	1st Grade	Science: Building rockets	Conditional logic and pattern recognition
Katherine	2nd Grade	Science: Properties of liquids (types of matter)	Pattern recognition, conditional logic, and building a computational artifact, testing and debugging

Table 1 Overview of PSTs and lessons.

and language scaffolds to support multilingual learners' (MLs) access to instruction; and (2) PSTs also developed their own self-efficacy beliefs throughout the integration and implementation process. In the following section we present each case as its own narrative, providing evidence that each PST came to the project with pre-existing beliefs about the value of CT/CS instruction. We then describe the key features of the lessons they designed and taught before exploring each PST's beliefs about ELD instruction within their lessons. Finally, each case ends with evidence highlighting changes in beliefs about CT integration.

ANDREW

Initial beliefs about CT integration

Andrew explained his motivation for participating in the project saying in his interview, "I was interested because I know how the future is based on technology and how we can use technology for educational purposes. I was curious to learn more about how I can use computer science logic to help out with lessons." His motivation to participate in the lesson integration work stemmed from beliefs about the importance of CT and CS instruction for all students. He framed his goals as figuring out if integrating CT "would help [students] with the lesson or if it would confuse them." He goes on to say, "what I saw in the lessons is that the students did pick up the computational thinking pretty easily and it actually did help them figure out the contents of the lesson more easily." This highlights his experience which reinforced beliefs about the value of CT instruction. In his pre-survey response, Andrew expressed beliefs that CT should look like "students using skills they know from computing to problem solve challenges in the classroom." He believes that his students are likely to be "tech-savvy" and will have had experiences with "computers and solving computer issues," which may inform the ways students can appropriate those experiences in order to solve problems within the classroom.

Features of designed and implemented lessons

Andrew chose to integrate conditional logic into two Eureka math fraction lessons. He introduced his class to the learning objective of his lessons before explaining that they were going to use conditional logic to help them solve the math problems. Andrew gave his class a definition of conditional logic and the example, "If it's raining, then recess is not outside." Andrew called on students to come up with their own examples before demonstrating how conditional logic can be applied to solving the fraction problems they were working on. Andrew drew a square for the class to see and wrote the sentence "If I draw a line down the middle of my square, then _____." To which students replied "you have halves." Throughout the lesson, Andrew had students partition shapes on their whiteboards and continued to pose questions utilizing an if/then sentence format. The second lesson followed a similar format but the content was focused on unit fractions.

Beliefs about ELD supports

In order to ensure that the lesson and content were accessible to all students, particularly multilingual learners, Andrew made sure to draw on students' background knowledge when discussing examples of conditional logic. He ensured each lesson had a visual component utilizing educational technology, and modeled solving the math problems using conditional logic (Figure 2). Students were assessed through an exit ticket where they had to

Figure 2 Andrew modeling CT-integrated math.

partition shapes and fill in a sentence frame similar to the ones modeled throughout the lesson. His design and implementation of lessons demonstrate an increased understanding of CT integrated lessons.

Beliefs about CT integration after designing and implementing lessons

In his interview, Andrew expressed beliefs that computational thinking, specifically conditional logic, functioned as a tool to support students' understanding of the math content. He also articulated beliefs that CT needs to be taught over time, reflecting ideas around coherence which was a key topic in the initial workshop for PSTs. He explained that if a CT aspect does not make sense to students right away, one could introduce another aspect and see what supports students' problem solving. He also stated that understanding "develops over time and it's unlikely for all of it to be understood to a tee by the students the first time around." His beliefs after designing and implementing lessons cannot be classified as new beliefs because he held beliefs about the importance of CT/CS education for students due to the increase in technology in society, but those beliefs developed through participation in lesson design and implementation, resulting in a more nuanced belief about what CT education should look like for students (Mead, 1934).

Despite beliefs around the success of the integration in his lessons, Andrew ranked them a 6 on a scale of 1–10, explaining that his students had a lot of energy which he found difficult to manage while completing his 3-day solo. Andrew believes that learning more about CT through designing and implementing CT integrated lessons framed his desire to continue integrating CT into his future classroom saying, "I will want to wherever I can really, especially if it will help them understand the lesson better then absolutely, I'd want to incorporate it wherever I could" (Interview). Andrew's desire to continue implementing CT-integrated lessons in his future classroom indicate the ways in which designing and implementing those lessons affirmed and deepened his beliefs about the importance of teaching CT and his own self-efficacy beliefs (Bandura, 1994).

SARAH

Initial beliefs about CT integration

Before participating in the program, Sarah stated in her interview that she "had a preconceived notion that computer science was just in the realm of computers and people who designed programs on the computers." However, she was motivated to participate in the program because she "never expected it to be something [she] could integrate into her classroom curriculum." She was interested in learning how integration worked and because she believes that "computer science is really important for students to learn in order to integrate with the world today." She had also seen a previous mentor teacher integrate CT into the classroom and that piqued her interest in learning about it. In her pre-survey response, Sarah believed that integrating CT into the classroom might look like having students create simple algorithms. Like Andrew, Sarah held beliefs about the importance of CT and CS instruction for students before participating in the lesson design and implementation work.

Features of designed and implemented lessons

Sarah decided to integrate CT into a science lesson that she was designing on her own, not revising an existing Science lesson. Her students knew she was interested in outer space and they had expressed interest in rockets. Sarah believed that integrating computational thinking into the rocket building lesson was a seamless fit. Sarah found integrating CT into a second rocket lesson to be more challenging saying, "the second lesson took a bit more planning that was more deliberate in making it work with computational thinking. But I think overall, I just had the idea and then I worked backwards to incorporate the computational thinking" (Interview). Sarah explained that she utilized the standards and objectives for second grade science instruction to help plan her lesson objectives. Her beliefs about the importance of CS and CT instruction motivated her initial participation in the work, however her participation in the workshop was comprised of instances reflecting the idea of participating in social processes that can shape and develop beliefs (Mead, 1934).

Sarah introduced her rocket lessons by asking students what a basic rocket is before explaining that they were going to use conditional logic to help with the lesson. Sarah shared a definition of conditional logic with her class and had students repeat the phrase "conditional logic." In her interview, Sarah said she thought the students were just repeating the phrase back without fully understanding what they were saying which prompted her to rip a piece of paper from her notebook and ask the students "what is the condition of the paper?" to help them connect condition to conditional. Next, Sarah had students share examples of conditional logic statements about the rocket. Students came up with examples like, "If I blow on the straw, then the rocket will blast off." Sarah then tested the claim and the students came up with more conditional logic statements.

After modeling the activity, the students made their own rocket and tested them outside. In the second lesson, Sarah reminded students of the definition of conditional logic before students "upgraded" their rockets and added fins. In terms of CT in the second lesson, Sarah continued to reinforce conditional logic and wanted to layer on pattern recognition. Her vision was for students to collect data on the distance of the rocket and examine patterns.

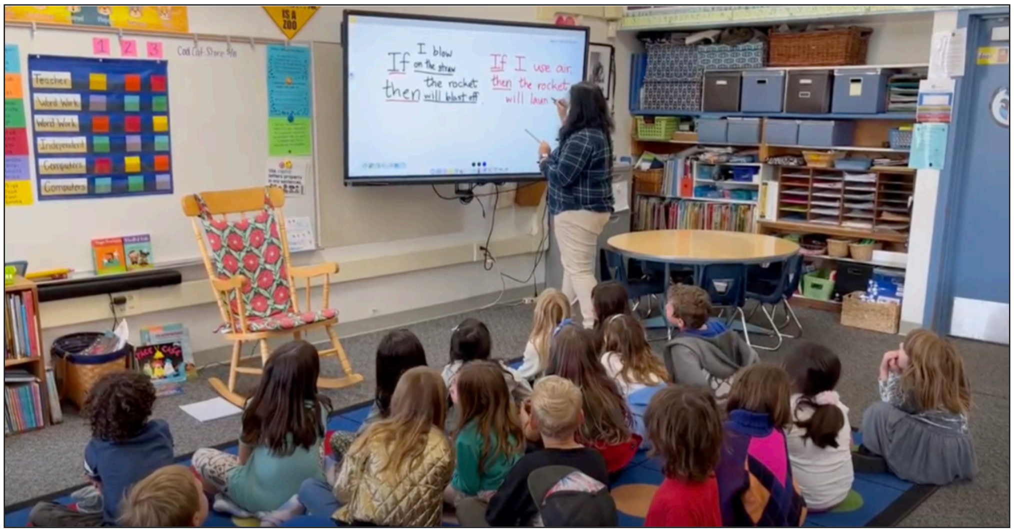

Figure 3 Sarah scaffolding students' CT language use.

She believes that the CT got too complex too fast for her students, showing a consideration for coherence:

> "The data collection, despite my telling them that data is just information… they didn't quite grasp data and I think it's just because they were overwhelmed with the vocabulary of already having conditional logic and if/then statements. Asking them to add another aspect on top of it… they just wanted to play with their rockets and didn't want to be bothered with measuring things… We did briefly touch on the pattern recognition with what a basic rocket does and with a complex design it flies further. They recognized those patterns but they weren't able to put it into words" (Interview).

Sarah's beliefs about CT integration and implementation deepened through her work and started to include how students learn CT.

Beliefs about ELD supports

In terms of ELD strategies, Sarah introduced new academic language in her lessons. Therefore, she reports breaking down the phrase "conditional logic" as an example of an effective strategy to support her multilingual learners. Additionally, she modeled using conditional logic as well as how to build a rocket (Figure 3). She also reports showing videos to support students with rocket related language. Intentionally integrating ELD into her lessons indicates beliefs that CT and ELD can be taught simultaneously and that students may need support accessing CT language. The ELD aspect of the lessons seemed to reinforce beliefs about strategies that Sarah believed were effective for supporting the language needs of her students.

Beliefs about CT integration after designing and implementing lessons

At the beginning of the project, Sarah expressed beliefs that computational thinking and computer science instruction are important for students but expressed that she could not imagine how to implement that type of instruction with students, particularly early elementary age students. In her interview, Sarah expressed feeling confident about integrating CT into her first of two lessons because "it just worked. It fit so well with the computational thinking." After participating in the project, Sarah believes that computational thinking instruction should happen over time saying, "I think it looks like an algorithm. In fact, it looks like a step-by-step process of achieving a certain goal but it takes time because, of course you have to build that understanding with the students and introduce them to language that they may find intimidating. But ultimately, when they realize they can grasp these concepts, they are very confident in using the terms. It just takes some time." By recognizing the need to develop students' CT understanding over time, Sarah demonstrates beliefs about how students learn CT and again shows an understanding of the importance of coherence. Throughout the integration and implementation process, Sarah's beliefs about CT integration expanded. Her beliefs now encompass notions of how students learn CT, ways to make CT instruction accessible to all students, and understandings of various aspects of CT.

Overall, Sarah expressed a positive attitude about the CT integration lessons she planned and implemented which shaped her desire to continue teaching CT in the future. Sarah said, "I never expected to enjoy it as much as I did. I've realized the students like learning new things and being experts. For them to be able to use complex terminology is really exciting. I would love to bring that to any future students I have" (Interview). Like Andrew, Sarah's positive experiences with CT integration and implementation supported self-efficacy beliefs (Bandura, 1994) which drive the desire to continue integrating CT in the future.

KATHERINE

Initial beliefs about CT integration

Katherine's motivation for joining the project stemmed from experiences she had being placed in a classroom with a mentor teacher who valued CT integration, had participated in CT integration professional development, and was actively integrating and teaching CT to her students. Katherine believed that participating in the project and learning more about CT would provide her with tools to make the adopted science curriculum more interesting and engaging for her students. Additionally, Katherine wanted to participate in the project because she was hoping to be hired by the district she was student teaching in. Katherine's experiences ultimately shaped her initial beliefs about CT integration. She said "In my placement we tie conditional logic and pattern recognition into our science lessons. Thinking about how things can change and be explained clearly is a key skill that I want my students to have" (Interview). While Andrew and Sarah were motivated to participate because they believed CT and CS instruction were important for all students, Katherine had experiences in a classroom where CT integrated lessons were common and she had seen the ways students could engage in those lessons, a pattern seen in prior work (Beach, 1994; Johnson, 1994). Katherine explained that she had seen examples of CT integrated science lessons and she had taught some of the lessons that her mentor teacher had designed. Katherine said, "when it came around to planning and teaching these lessons, I felt like I really saw what a lesson was that had implemented computational thinking and seeing some of the connections that can be made to ELD was really helpful" (Interview).

Features of designed and implemented lessons

Katherine chose to integrate CT into a sequence of three science lessons where students explored the properties of liquids. Students had access to bottles with various liquids in them throughout the three lessons. During the first lesson, students were tasked with exploring the liquids and making observations about what happened when they shook the bottles or rolled them down different objects. Katherine explained that students were implicitly using pattern recognition to make observations about the liquids.

In the second lesson, students continued to explore the liquids but had to identify different properties about the liquids. There was a heavy focus on using conditional logic to talk about the liquids and their properties. Katherine modeled how to explore and use conditional logic while her students were sitting on the carpet before sending them back to their table groups to explore. She then walked around the classroom and supported students in crafting conditional logic statements about the liquids. She differentiated her support for students, providing some

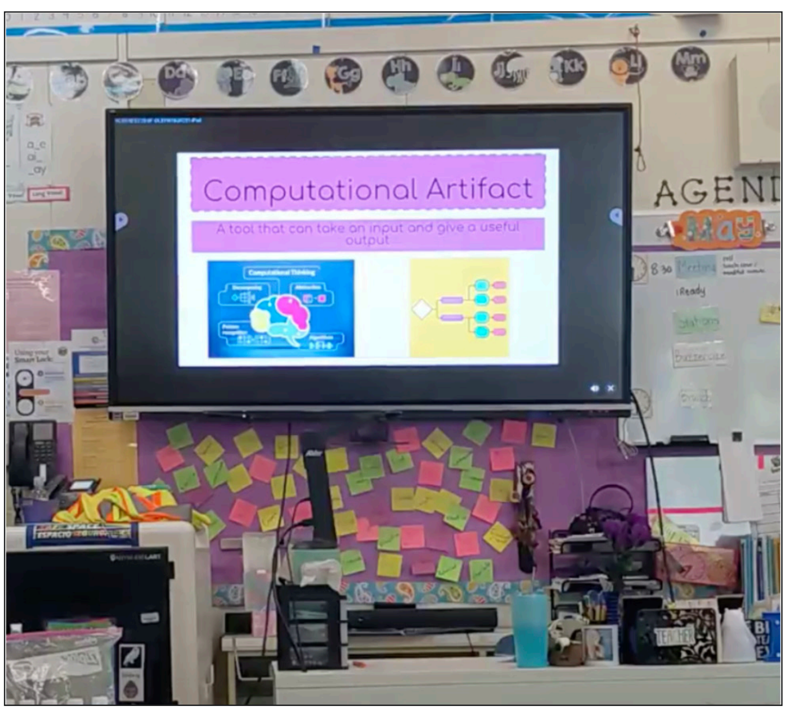

Figure 4 Materials used to introduce students to computational artifacts.

with more structured prompting such as "if I shake the hand soap, then ___" while asking others to put their idea into a conditional logic sentence. Katherine's intentional ELD instruction demonstrates her beliefs that CT and ELD instruction can support student learning at the same time.

In her third lesson, Katherine introduced students to the concept of a computational artifact by providing a definition and showing them examples of a flow chart (Figure 4). She then modeled the activity of building a flowchart, which she saw as a computational artifact, with a property input that led to a liquid output. She had her students draw on the conditional logic statements they had come up with in the lesson before and asked them to test and debug their flowchart. Katherine reported assessing her students informally throughout all of the lessons. The major challenge Katherine believed influenced her lesson implementation was the amount of time she was able to spend on her lessons. She said if she had been in her own classroom she would have hung up the posters and done more testing and debugging but being a student teacher meant she was operating on her mentor teachers' schedule. The decisions Katherine made about the aspects of CT she integrated into her lessons and the ways in which they build over time highlight her beliefs about how students learn CT.

Overall, Katherine believed her lessons went well. She thought that her conditional logic lesson went particularly well saying:

> "The chart of our conditional logic statements, I thought, was a really good representation of what we had learned that they could look back on and have a representation of the language they were using. They got to a place where they could produce that language and recall that vocabulary, I was really impressed and I felt like it was the perfect amount of information I had given them to chew on" (Interview)

Katherine was also proud of her computational artifact lesson but believed she needed to provide her students more support. She said that there "was a lot of learning happening and it was creative and I'm happy with how it turned out. It just didn't feel as clean [as the conditional logic lesson]."

Beliefs about ELD supports

Katherine believed ELD was central to her lessons and to computational thinking instruction more broadly. Questions about how to best support students' ELD was at the forefront of her lesson planning process. In terms of strategies she actually implemented while teaching her lessons, Katherine provided visual representations along side the vocabulary words, provided sentence frames to support language use, being mindful of how students were using the language through prioritizing talking over writing vocabulary words, and providing physical representations of the liquids for each group to have access to. Katherine's intentional ELD integration demonstrates her beliefs about making CT instruction accessible to all of her students. Katherine also explained that the design and implementation process demonstrated that CT-integrated lessons "can be a place where you can integrate ELD and bring so much more [for the students]" (Interview). This demonstrates a shift in her beliefs about the learning opportunities that can be embedded in CT-integrated lessons.

Beliefs about CT integration after designing and implementing lessons

At the beginning of the project, Katherine had beliefs about CT integration and instruction that were shaped by the work she was doing with her mentor teacher. Katherine believes that integrating CT into her lessons enhanced the existing science curriculum and her experiences designing and implementing lessons shaped her beliefs that ELD and CT can happen concurrently. She said, "I saw how CT can really add to [the science] and it can be a place where you can integrate ELD and just bring so much more…CT can connect to more than I thought it could" (Interview). In her interview, Katherine defined CT as "ways to break problems down or to think about problems or categorize problems differently and have approaches to problems. So whether you're using abstraction or conditional logic, these are different approaches to how you can think about what steps you're taking to solve a problem." Katherine believes that she will continue to use aspects of CT to support students' language use and that algorithms and conditional logic are simple aspects she can have students engage with throughout the year. Like the other two PSTs, Katherine's existing beliefs were revised based on her experiences with the integration and implementation work, echoing prior work where self-efficacy beliefs were strengthened because of the positive experiences participants had (Beach, 1994; Johnson, 1994).

DISCUSSION

This study examined how participation in a design project supported and shifted PSTs beliefs about CT. Participation in design work functions as participation in a social process, which Mead (1934) claims is important to the development of beliefs. The three PSTs highlighted in this study joined the project with pre-existing beliefs about CS/CT education. This study demonstrates how the experience of successfully co-designing and implementing lessons that integrated CT and fostered beliefs that they could support their multilingual learners through the use of particular instructional strategies. After designing and implementing lessons, the three PSTs' beliefs about CS/CT integration changed- PSTs were more detailed about what CS/CT education should look like in practice (e.g., coherence of learning where it builds incrementally) and had developed beliefs in their own ability to develop and teach CT-integrated lessons.

PSTs HAD PRE-EXISTING BELIEFS ABOUT CS EDUCATION OR CT INTEGRATION

All 3 PSTs joined the project with existing beliefs about the importance of teaching CS and CT to their students. However, Andrew and Sarah voiced beliefs about CS and the importance of CS education for students' futures, they did not realize CT could support students' CS understandings and be integrated into their classrooms. This differs from Katherine's pre-existing beliefs which highlighted the importance of CT integration because her mentor teacher prioritized CT integration in their own teaching. It is important to acknowledge that all PSTs had beliefs before participating in the project because beliefs do not develop in a vacuum but over time and through participation in social processes (Mead, 1934). This finding is of particular note because Katherine was the only PST who had beliefs specific to CT integration and was the only PST who had already been exposed to CT integration in her student teaching placement. This reinforces the notion of the role of participation in social processes, engaging with the external world, and making-meaning internally (Biesta & Tröhler, 2016). This finding is reinforced by Love et al. (2022) who suggest that teachers' beliefs about the value of CT/CS integration work can be positively influenced by participation in professional development.

PSTs HAD DIFFERING BELIEFS ABOUT CT INTEGRATION

While all three PSTs were successful in their design and implementation, each PST took on varying levels of CT to integrate into their lessons. Andrew focused on one aspect of CT, Sarah focused on two aspects and introduced them as separate concepts, while Katherine integrated two aspects and had students use them together. When looking across cases, it appears that Andrew chose the most straightforward way to integrate CT into his lesson, focusing on one aspect for both lessons. Sarah chose two aspects of CT to focus on but they each functioned on their own. Katherine also chose two aspects of CT but students were using them together by the third lesson. This shows how Katherine's beliefs about CT integration differ from the other two PSTs because she believed that conditional logic and computational artifacts could be taught together and students would be able to engage in both aspects. Katherine was the only PST who had a mentor teacher who taught CT regularly, which may have influenced her beliefs about CT integration and highlights the role a mentor teacher can have on PSTs' beliefs about instruction. Coenraad et al. (2021) found that teachers who integrated CT into science lessons did so to varying degrees and the variation seemed to differ across concepts. This reinforces the notion that integration can happen at different levels as is visible with the PSTs in this study.

Additionally, Izadinia (2015) suggests that the type of relationship PSTs have with their mentor teachers can shape their professional identity as a teacher. It is possible that Katherine's positive relationship with her mentor teacher allowed her to feel supported as she completed the lesson design and implementation work, ultimately increasing her self-efficacy beliefs. The relationship with her mentor teacher also provided her opportunities to engage with CT-integrated lessons and collaborate with a teacher who had experience with CT integration, functioning as a social process which can influence belief development (Mead, 1934).

PSTs BELIEVED THEY COULD PROVIDE ELD SUPPORTS TO ENSURE ALL STUDENTS WERE ENGAGING WITH CT IN THEIR LESSONS

All 3 PSTs believed that they could support their ML students' engagement with their CT-integrated lessons by including intentional ELD instructional strategies in their lessons. The use of intentional ELD strategies demonstrate PSTs' beliefs that ELD and CT can be taught together and that students will need specific supports to be able to engage with the CT aspects in the lessons. In addition to beliefs about the use of intentional ELD, Katherine believed that CT provided opportunities to enhance students' language use and vocabulary development. PSTs beliefs about ELD strategies aligns with Jacob et al. (2018)'s principles for CT language development including explicit vocabulary instruction and supporting emerging literacy skills with the use of strategies such as sentence frames. Jacob et al. (2018) also discuss the importance of culturally relevant curriculum that results in students creating artifacts informed by their own interests. Sarah was the only PST who chose to develop her own lessons (not using the district adopted curriculum) based on her students' interests in rockets and space, perhaps demonstrating an emerging belief about the importance of culturally relevant curriculum.

PSTs' BELIEFS ABOUT CT INTEGRATION CHANGED AFTER DESIGNING AND IMPLEMENTING LESSONS

All three PSTs held beliefs about the importance of CS education, however after they designed and implemented

CT-integrated lessons, their beliefs about CS education changed. Sarah expressed beliefs that CT learning should happen over time. Andrew expressed beliefs that CT can help students understand lesson content better. Katherine believed that CT can enhance lessons. All of the PSTs were able to discuss particular aspects of CT and explain how they can help students solve problems. While PSTs did not experience a drastic change of beliefs such as from not believing in CS education to believing, their beliefs were refined over time through their participation in a social process involving designing and implementing CT-integrated lessons. This finding reinforces Margulieux et al. (2022)'s study examining how PSTs' definitions of CT evolved over time as they gained more experience with CT integration. This refinement of beliefs exemplifies the promise of transformative teacher education. These PSTs took the opportunity to participate in a learning experience that happened outside of their teacher preparation requirements and these findings indicate the transformative potential of this work.

CONCLUSION

If PSTs already have beliefs about the importance of CT instruction, then teacher education programs must provide the support and opportunities for PSTs to engage in the work in order to deepen existing productive beliefs or opportunities for beliefs to change through rich teacher learning tasks (e.g., design work). While this work was embedded in a larger grant funded project, the scope of the design work in this study offers the possibility that there are opportunities for methods course instructors to include CT integrated lesson design projects within existing assignments. Providing necessary information about CT and examples of integration before offering opportunities for PSTs to integrate CT into lessons they are already required to design and implement, perhaps a supplemental assignment, would be one way to begin to leverage PSTs' existing beliefs and provide opportunities for them to build upon those beliefs.

Another important implication of our study is revealed by challenges faced with recruiting and retaining participants. Many PSTs chose not to participate due to conflicting tasks in their teacher education program, mainly, the teacher performance assessment. Even with the $500 payment, the potential hiring advantage in the school district, and the personal guidance in developing their integrated CT lessons, half of the PSTs placed in the district said that the performance assessment (CalTPA) was an overwhelming obstacle to their participation. And like the PSTs in Frazier and Trekles' (2020) study, our participants all reported that the performance assessment was a burden that prevented them from focusing on their CT lessons. Many other teacher educators have documented the overload of teaching performance assessments and concluded that whatever value they might have pales when compared to the time and pressure placed on program faculty and PSTs (Cronenberg et al., 2016). We understand the arguments made in favor of teaching performance assessments (e.g., Whittaker et al., 2018), but if teacher education hopes to be transformative, inviting PSTs to experiment with new methods and curriculum, such as CT integration, then the completion of a performance assessment represents an apotheosis of educational conservation and the death of the progressive, experimental schooling that Dewey advocated (Lagemann, 1996).

LIMITATIONS

This study took place with PSTs placed in a school district that has emphasized the importance of CT/CS instruction for the past 4 years. Because of this focus, some of the mentor teachers had their own beliefs, about and experiences, with CT/CS instruction and were able to provide their PSTs more support than other mentor teachers could. Given the support of the partner school district, we acknowledge that our results may not be entirely replicable in other contexts, however there remain implications for the ways in which PSTs can be supported in CT integration work. The small sample size may limit the generalizability of the findings, but our results offer an example of possible activities that can support PST learning in their placement context.

APPENDIX 1

PRE-SURVEY QUESTIONS

1. What is your name?
2. Where are you student teaching?
3. What grade level are you student teaching in?
4. What experiences have you had with computer science or computational thinking?
5. What do you think it should look like to have students use and learn about "computational thinking" in your classroom?
6. What do you hope to learn or gain from participating in cSINO?
7. What might make participating in cSINO challenging?

APPENDIX 2

SEMI-STRUCTURED INTERVIEW PROTOCOL

Thanks for taking the time to talk today... I'll ask some questions about you and your lessons. They are designed to help us understand how you integrated CS and/or Computational Thinking into a lesson or curriculum. We will keep the details of your reflection confidential. In our research papers, we might quote you, but we won't say it was you. We might also share the lesson plan you created with other educators.

SECTION 1: GOALS

1. What did *you* hope to learn or gain from having the opportunity to integrate CS and/or Computational Thinking into two lessons?
2. In what ways do you feel the goals you had were met (or not)?
3. How did the importance Santa Cruz City Schools placed on this work influence your decision to participate (if at all)?

SECTION 2: IDEAS ABOUT COMPUTATIONAL THINKING

4. How would you explain what "computational thinking" is to someone not familiar with it? (Prompt with aspects of CT [e.g., "decomposition," "algorithms," "conditional logic (IF...THEN...)"] as needed)
5. A colleague at your future school is curious about how to best integrate "computational thinking" into their class. What advice would you give them ? (Probe for what learning might look like over time if not mentioned, e.g., several lessons)

SECTION 3: REFLECTION ON TEACHING LESSON

6. What grade/subject did you teach for your lessons?
7. Describe the lessons your students engaged in that integrated CS or Computational Thinking.
8. What was the overall goal of the lesson?
9. What CS/Computational Thinking concepts did students engage with?
10. What, if any, English Language Development (ELD) strategies did you use during your lessons?
11. How did you assess student learning in this activity?
12. On a scale of 1–10, how do you feel the lessons went? 1 = needs substantial modification; 10 = these are some of my best lessons. Please explain why you chose the rating in the previous question.
13. If you could continue to do lessons after this lesson with students, what would you want them to do next?

SECTION 4: REFLECTION ON PLANNING LESSON

14. Describe how you went about planning the lessons students engaged in.
15. What proved helpful in planning your lessons? How so?
16. What proved challenging when planning your lessons? How so? (Probe for institutional barriers if not mentioned, e.g., school/district expectations, MA/C requirements, etc.)
17. Looking back, what additional support(s) would have been useful to have in planning your lessons?
18. How much support did your cooperating teacher offer?

CLOSE

19. What do you think about trying to continue to integrate CS or Computational Thinking experiences into your future classroom?
20. Have you started the CS endorsement class?
    a. If yes, how far have you gotten? When do you anticipate finishing? What have you learned from it?
    b. If not, why have you not started it? Do you plan on starting it?
21. Is there anything else we have not asked about that you would like to tell us about? If so, please share.
22. Please email me or share a copy of your lesson plan.

DATA ACCESSIBILITY STATEMENT

The data that support the findings of this study are available from the corresponding author, [RD], upon reasonable request.

ACKNOWLEDGEMENTS

We are grateful to our district partners within our research-practice partnership for their commitment to this work.

Research was approved by the IRB board. Reference # HS-FY2023–51.

FUNDING INFORMATION

This research was funded by the National Science Foundation (#2219422).

COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR AFFILIATIONS

Rachael Dektor orcid.org/0009-0000-7391-3618
University of California, Santa Cruz, United States
Samuel Severance orcid.org/0000-0003-0055-3572
Northern Arizona University, United States
Kip Téllez orcid.org/0000-0002-6314-6459
University of California, Santa Cruz, United States

REFERENCES

ACM, Code.org, CSTA, Cyber Innovation Center, & **National Math and Science Initiative.** (2016). K–12 Computer Science Framework. Retrieved from http://www.k12cs.org

Arastoopour Irgens, G., Dabholkar, S., Bain, C., Woods, P., Hall, K., Swanson, H., … & **Wilensky, U.** (2020). Modeling and measuring high school students' computational thinking practices in science. *Journal of Science Education and Technology*, *29*(1), 137–161. DOI: https://doi.org/10.1007/s10956-020-09811-1

Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran (Ed.), *Encyclopedia of human behavior* (Vol. 4, pp. 71–81). Academic Press.

Beach, S. A. (1994). Teachers' theories and classroom practice: Beliefs, knowledge, or context? *Reading Psychology*, *15*(3), 189−196. DOI: https://doi.org/10.1080/0270271940150304

Biesta, J., & **Tröhler, G.** (2016). Introduction: George Herbert Mead and the development of a social conception of education. In J. Biesta & G Tröhler (Eds.), *Philosophy of Education*. Taylor & Francis.

California State Board of Education. (2018). *Computer Science Standards for California Public Schools*.

Century, J., Ferris, K. A., & **Zuo, H.** (2020). Finding time for computer science in the elementary school day: A quasi-experimental study of a transdisciplinary problem-based learning approach. *International Journal of STEM Education*, *7*(1), 1–16. DOI: https://doi.org/10.1186/s40594-020-00218-3

Charmaz, K. (2002). Qualitative interviewing and grounded theory analysis. In J. F. Gubrium & J. S. Holstein (Eds.), *Handbook of Interview Research: Context and Method* (pp. 675–694). Thousand Oaks, CA: Sage.

Coburn, C. E., & **Penuel, W. R.** (2016). Research–practice partnerships in education: Outcomes, dynamics, and open questions. *Educational researcher*, *45*(1), 48–54. DOI: https://doi.org/10.3102/0013189X16631750

Coenraad, M., Cabrera, L., Killen, H., Plane, J., & **Ketelhut, D. J.** (2021). Computational thinking integration in elementary teachers' science lesson plans. In A. Ottenbreit-Leftwich & A. Yadav (Eds.), *Computational thinking in PreK-5: Empirical evidence for integration and future directions* (pp. 11–18). DOI: https://doi.org/10.1145/3507951.3519283

Creswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five approaches*. (2nd ed.). Thousand Oaks, CA: Sage.

Cronenberg, S., Harrison, D., Korson, S., Jones, A., Murray-Everett, N. C., Parrish, M., & **Johnston-Parsons, M.** (2016). Trouble with the edTPA: Lessons Learned from a Narrative Self-Study. *Journal of Inquiry and Action in Education*, *8*(1), 109–134.

Daniels, J. R., & **Varghese, M.** (2020). Troubling practice: Exploring the relationship between Whiteness and practice-based teacher education in considering a raciolinguicized teacher subjectivity. *Educational Researcher*, *49*(1), 56–63. DOI: https://doi.org/10.3102/0013189X19879450

De Vries, H., Elliott, M. N., Kanouse, D. E., & **Teleki, S. S.** (2008). Using pooled kappa to summarize interrater agreement across many items. *Field Methods*, *20*(3), pp. 272–282. DOI: https://doi.org/10.1177/1525822X08317166

Enderle, P., Dentzau, M., Roseler, K., Sutherland, S., Grander, E., Hughes, R, … & **Saka, Y.** (2014). Examining the influence of RETs on science teacher beliefs and practice. *Science Teacher Education*, *98*(6), 1077–1108. DOI: https://doi.org/10.1002/sce.21127

Fortus, D., & **Krajcik, J.** (2012). Curriculum coherence and learning progressions. In *Second international handbook of science education* (pp. 783–798). Springer. DOI: https://doi.org/10.1007/978-1-4020-9041-7_52

Frazier, D. K., & **Trekles, A. M.** (2020). Preservice teacher perceptions of coding in literacy instruction. *Journal of Computer Science Integration*, *3*(1), 1–34. DOI: https://doi.org/10.26716/jcsi.2020.03.1.1

Google Inc., & **Gallup Inc.** (2016). *Diversity gaps in computer science: Exploring the underrepresentation of girls, Blacks and Hispanics*. Retrieved from http://goo.gl/PG34aH

Grover, S., & **Pea, R.** (2013). Computational thinking in K–12: A review of the state of the field. *Educational Researcher*, *42*(1), 38–43. DOI: https://doi.org/10.3102/0013189X12463051

Grover, S., & **Pea, R.** (2018). Computational thinking: A competency whose time has come. *Computer science education: Perspectives on teaching and learning in school*, *19*(1), 19–38. DOI: https://doi.org/10.5040/9781350057142.ch-003

Harlow, D. B., Dwyer, H. A., Hansen, A. K., Iveland, A. O., & **Franklin, D. M.** (2018). Ecological design-based research for computer science education: Affordances and effectivities for elementary school students. *Cognition and Instruction*, *36*(3), 224–246. DOI: https://doi.org/10.1080/07370008.2018.1475390

Hume, D. (2007). *Enquiry concerning human understanding*. DOI: https://doi.org/10.1093/owc/9780199549900.001.0001

Israel, M., Liu, R., Yan, W., Sherwood, H., Martin, W., Fancsali, C., & **Rivera-Cash, E.** (2021). Understanding barriers to school-wide computational thinking integration at the elementary grades: Lessons from three schools. In A. Ottenbreit-Leftwich & A. Yadav (Eds.), *Computational thinking in PreK-5: Empirical evidence for integration and future directions* (pp. 64–71). DOI: https://doi.org/10.1145/3507951.3519289

Izadinia, M. (2015). A closer look at the role of mentor teachers in shaping preservice teachers' professional identity. *Teaching and Teacher Education*, *52*. DOI: https://doi.org/10.1016/j.tate.2015.08.003

Jacob, S., Nguyen, H., Tofel-Grehl, C., Richardson, D., & **Warschauer, M.** (2018). Teaching computational thinking to English learners. *NYS TESOL Journal*, *5*(2).

Janssen, F., Grossman, P., & **Westbroek, H.** (2015). Facilitating decomposition and recomposition in practice-based teacher education: The power of modularity. *Teaching and teacher education*, *51*, 137–146. DOI: https://doi.org/10.1016/j.tate.2015.06.009

Johnson, K. E. (1994). The emerging beliefs and instructional practices of preservice English as a second language teachers. *Teaching and Teacher Education*, *10*(4), 439–452. DOI: https://doi.org/10.1016/0742-051X(94)90024-8

Kafai, Y. B., Ching, C. C., & **Marshall, S.** (1997). Children as designers of educational multimedia software. *Computers & Education*, *29*(2–3), 117–126. DOI: https://doi.org/10.1016/S0360-1315(97)00036-5

Klopfer, E., Yoon, S., & **Um, T.** (2005). Teaching complex dynamic systems to young students with StarLogo. *Journal of Computers in Mathematics and Science Teaching*, *24*(2), 157–178.

Korthagen, F. A., Kessels, J., Koster, B., Lagerwerf, B., & **Wubbels, T.** (2001). *Linking practice and theory: The pedagogy of realistic teacher education*. Routledge. DOI: https://doi.org/10.4324/9781410600523

Lagemann, E. C. (1996). Experimenting with Education: John Dewey and Ella Flagg Young at the University of Chicago. *American Journal of Education*, *104*(3), 171–185. DOI: https://doi.org/10.1086/444127

Loeb, L. E. (1990). The priority of reason in Descartes. *The Philosophical Review*, *99*(1), 3–43. DOI: https://doi.org/10.2307/2185202

Love, T. S., Bartholomew, S. R., & **Yauney, J.** (2022). Examining changes in teachers' beliefs toward integrating computational thinking to teach literacy and math concepts in grades k-2. *Journal for STEM Education Research*. DOI: https://doi.org/10.1007/s41979-022-00077-3

Margulieux, L. E., Enderle, P., Clarke, P. J., King, N., Sullivan, C., Zoss, M., & **Many, J.** (2022). Integrating cominting into preservice teacher preparation programs across the core: Language, mathematics, and science. *Journal of Computer Science Integration*, *5*(1), 1–16. DOI: https://doi.org/10.26716/jcsi.2022.11.15.35

Martin, A., McAlear, F., & **Scott, A.** (2015). *Path not found: Disparities in access to computer science courses in California high schools*. Level Playing Field Institute. Received from https://eric.ed.gov/?id=ED561181

Mead, G. H. (1934). *Mind, Self, and Society*. The University of Chicago Press.

Miller, D. L. (1973). George Herbert Mead: Symbolic interaction and social change. *The Psychological Record*, *23*, 294–304. DOI: https://doi.org/10.1007/BF03394172

National Academies of Sciences, Engineering, and Medicine. (2018). *Assessing and Responding to the Growth of Computer Science Undergraduate Enrollments*. National Academies Press. DOI: https://doi.org/10.17226/24926

National Academies of Sciences, Engineering, and Medicine. (2021). *Cultivating Interest and Competencies in Computing: Authentic Experiences and Design Factors*. National Academies Press. DOI: https://doi.org/10.17226/25912

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: The National Academies Press.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, *62*(3), 307–332. DOI: https://doi.org/10.3102/00346543062003307

Penuel, W. R. (2019). Infrastructuring as a practice of design-based research for supporting and studying equitable implementation and sustainability of innovations. *Journal of the Learning Sciences*, *28*(4–5), 659–677. DOI: https://doi.org/10.1080/10508406.2018.1552151

Pozos, R. K., Severance, S., Denner, J., & **Tellez, K.** (2022). Exploring design principles in computational thinking instruction for multilingual learners. *Teachers College Record (1970)*, *124*(5), 127–145. DOI: https://doi.org/10.1177/01614681221104043

Reiser, B. J., Novak, M., McGill, T. A., & **Penuel, W. R.** (2021). Storyline units: An instructional model to support coherence from the students' perspective. *Journal of Science Teacher Education*, *32*(7), 805–829. DOI: https://doi.org/10.1080/1046560X.2021.1884784

Ritzman, R. L., & **Tomaskovic-Devey, D.** (1992). Life chances and support for equality and equity as normative and counternormative distribution rules. *Social Forces*, *70*(3), 745–764. DOI: https://doi.org/10.1093/sf/70.3.745

Sato, M., & **Loewen, S.** (2022). The research-practice dialogue in second language learning and teaching: Past, present, and future. *The Modern Language Journal*, *106*(3), 509–527. DOI: https://doi.org/10.1111/modl.12791

Severance, S., Penuel, W. R., Sumner, T., & **Leary, H.** (2016). Organizing for teacher agency in curricular co-design. *Journal of the Learning Sciences*, *25*(4), 531–564. DOI: https://doi.org/10.1080/10508406.2016.1207541

Wang, J., Hong, H., Ravitz, J., & **Hejazi Moghadam, S.** (2016). Landscape of K-12 computer science education in the US: Perceptions, access, and barriers. *Proceedings of the 47th ACM Technical Symposium on Computing Science Education*, 645–650. DOI: https://doi.org/10.1145/2839509.2844628

Weintrop, D., Walkoe, J., Walton, M., Bih, J., Moon, P., Elby, A., Bennett, B., & **Kantzer, M.** (2021). Sphero.Math: A computational thinking-enhanced fourth grade mathematics curriculum. In A. Ottenbreit-Leftwich & A. Yadav (Eds.), *Computational thinking in PreK-5: Empirical evidence for integration and future directions* (pp. 39–46). DOI: https://doi.org/10.1145/3507951.3519286

Welch, L. E., Shumway, J. F., Clarke-Midura, J., & **Lee, V. R.** (2022). Exploring measurement through coding: Children's conceptions of a dynamic linear unit with robot coding toys. *Education Sciences*, *12*(2), 143. DOI: https://doi.org/10.3390/educsci12020143

Wengraf, T. (2001). *Qualitative research interviewing*. Sage Publications. DOI: https://doi.org/10.4135/9781849209717

Whittaker, A., Pecheone, R. L., & **Stansbury, K.** (2018). Fulfilling our educative mission: A response to edTPA critique. *Education Policy Analysis Archives*, *26*, 30. DOI: https://doi.org/10.14507/epaa.26.3720

Wilson, C., Sudol, L. A., Stephenson, C., & **Stehlik, M.** (2010). *Running on empty: The failure to teach k–12 computer science in the digital age*. ACM. DOI: https://doi.org/10.1145/3414583

Yadav, A., Gretter, S., Good, J., & **McLean, T.** (2017). Computational thinking in teacher education. In *Emerging research, practice, and policy on computational thinking* (pp. 205–220). Springer. DOI: https://doi.org/10.1007/978-3-319-52691-1_13

Yadav, A., Hong, H., & **Stephenson, C.** (2016). Computational thinking for all: Pedagogical approaches to embedding 21st century problem solving in K–12 classrooms. *TechTrends*, *60*, 565–568. DOI: https://doi.org/10.1007/s11528-016-0087-7

TO CITE THIS ARTICLE:

Dektor, R., Severance, S., & Téllez, K. (2024). How do Preservice Teachers Learn to Teach Integrated Computational Thinking?: Evidence from Planning, Enactment, and Reflection. *Journal of Computer Science Integration,* 7(1): 2, pp. 1–16. DOI: https://doi.org/10.26716/jcsi.2024.06.27.54

Submitted: 23 July 2023 **Accepted:** 19 June 2024 **Published:** 27 June 2024

Journal of Computer Science Integration is a peer-reviewed open access journal published by Armacost Library, University of Redlands.