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Leveraging Virtual Professional Development to Build Computational Thinking Literacies in English Language Arts Classrooms

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This article describes the Infusing Computing project, a 4-year study designed to support middle and high school teachers in infusing computational thinking (CT) into their disciplinary teaching. Due to the COVID-19 pandemic, weeklong workshops held in summer 2020 were shifted to a virtual format and utilized emerging technology tools, synchronous and asynchronous sessions, explicit collaborative scaffolds, networking, and digital badging. Specifically, this study examined the experiences of English language arts (ELA) teachers (14 middle school, 13 high school) who participated in the virtual Infusing Computing workshops. Findings demonstrated that ELA teachers were able to leverage learning successfully from virtual PD to infuse CT into existing curricula, although teachers differed in the ways that they appropriated and adapted pedagogical tools for CT infusion.

To prepare learners for the challenges of the modern world, educators and students alike must learn how to consume and produce a variety of texts using 21st-century tools. Increasingly, researchers are interested in determining how computational thinking (CT), which refers to problem-solving practices inherent to the computer science discipline (Wing, 2006), can support this work – not only in science, technology, engineering, and mathematics (STEM) classrooms, but in English language arts (ELA), social studies, and the arts as well.

An emerging body of research suggests that integrating CT into disciplinary instruction can empower learners to become innovative writers of new media, rather than merely consumers (Brennan & Resnick, 2012; Jacob & Warschauer, 2018). However, to create new opportunities for students to critique and create multimodal texts using computational tools (Hestness et al., 2018; Smith & Shen, 2017), ELA teachers need comprehensive support, including access to high-quality professional development (PD).

The study reported here drew on data collected as part of the Infusing Computing initiative. The 4-year project was designed to support teachers in infusing CT into their disciplinary teaching through weeklong summer PD workshops and ongoing academic year supports, including webinars and technical assistance. In summer 2021, the 3rd year of Infusing Computing, the PD was redesigned as a virtual conference due to the COVID-19 pandemic. We employed emerging technology tools, synchronous and asynchronous sessions, explicit collaborative scaffolds, networking, and digital badging (Jocius et al., 2021) to support over 150 middle and high school teachers during a weeklong PD session.

This study is grounded in a multiple theoretical perspective approach (Labbo & Reinking, 1999) that incorporates CT frameworks in educational contexts (Grover & Pea, 2013; Wing, 2006), CT as literacy practice (Jacob & Warschauer, 2018; Kafai et al., 2020), and teacher PD (Grossman et al., 1999). We examined the experiences of ELA teachers (14 middle school, 13 high school) as they learned to infuse CT into disciplinary teaching during and following a virtual PD experience. Our work was guided by three research questions:

- How does participating in a virtual PD impact ELA teachers' understandings and beliefs about CT infusion?
- How do ELA teachers connect CT concepts to disciplinary standards and teaching practices?
- How do ELA teachers appropriate and adapt pedagogical tools for infusing CT into their classrooms?

This article concludes with implications for designing virtual PD opportunities, as well as suggestions for future research to better understand and document how CT can be used to reimagine ELA teaching and learning.

Literature Review

CT in Educational Contexts

As society adapts to the changes wrought by the influx of digital tools and spaces, educators need to be adaptive experts, who are able to leverage a variety of innovative pedagogical practices while also remaining responsive to changing contexts and needs (Love, 2009, p. 542). Never had this shift to virtual learning and the need to be adaptive been more necessary than in the pivot to emergency remote learning, as occurred during the Covid-19 global pandemic.

Infusing CT into disciplinary teaching can help prepare learners with the foundational knowledge, skills, and practices necessary to be informed citizens who are active users and producers of technology that is omnipresent in society. It also provides opportunities to consume and produce texts critically, solve problems, design systems, and understand human behavior by drawing on the concepts of computer science (Papert, 1980; Wing, 2006).

The problem-solving processes inherent in CT provide students with an opportunity to engage with content and promote the capability for creation and innovation (Cropley, 2015). CT promotes abstractions of real-world problems and makes concepts more concrete to provide an effective tool for student engagement, learning, and leadership.

As CT and computer science begin to impact more P-12 classrooms, CT knowledge, skills, and dispositions need to be fully integrated into teaching and learning processes. This work involves considering the numerous and ongoing debates as to what CT entails, how best to teach it, and how to support teachers' development of pedagogical content knowledge (Yadav et al., 2017). Further, even as CT is promoted as an essential competence that should be included in every student's skill set (Shute et al., 2017), educators must grapple with multiple barriers to widespread adoption in schools (Grover & Pea, 2013), including equitable access to technology, misconceptions about CT and its place within content area classrooms, and a lack of training for teachers (Chang & Peterson, 2018; Israel et al., 2015).

Framing CT instruction as disciplinary practice can lead students to develop understandings of disciplinary CT with domain-specific definitions that serve to highlight and enhance disciplinary practices. This approach shifts CT instruction from a view of skills that are generalizable across the curriculum to a disciplinary perspective of practices specific to the specialized language, knowledge, and habits of thinking within particular subject areas. As teachers consider connections between new CT learning in their content areas, new opportunities emerge to reflect on and share their practices, reconsider their understanding of learning and teaching, and coconstruct new knowledge (Achinstein, 2002; Chan & Pang, 2006). In short, understanding CT as a disciplinary practice allows educators to build on theoretical frameworks from other disciplines, while also carving out space for educators and learners that need to be adaptive to emerging knowledge, skills, and tools.

CT as Literacy Practice

Nascent educational theories of CT have expanded more traditional conceptualizations of CT to incorporate the cultural processes needed to embed it in instruction (Li et al. 2020), with a particular focus on how CT can support social and critical literacy practices (Kafai et al., 2020). Kafai et al., for example, detailed three emergent conceptual framings. Cognitive computational thinking, which is described as the dominant theoretical framing, focuses on building student knowledge of CT concepts, practices, and perspectives in relation to problem-solving. This framing is contrasted by two additional framings: situated computational thinking, which involves collaborative and social construction of multimodal products using tools like Scratch, and critical computational thinking, which emphasizes “an examination of and resistance to oppressive power structures” through computing (p. 47).

For ELA teachers, whose work often focuses on supporting students’ abilities to analyze, interpret, and create texts using multiple modes and tools, understanding CT as a social and cultural process of text consumption and production can open new opportunities for connecting disciplinary practices and CT concepts. ELA classrooms also offer valuable contexts for thinking about the affordances and constraints of producing and consuming computational texts. In short, educators and students need to be computationally literate.

Other researchers have begun attendimg to the situated and critical framings of CT in both theory and empirical work. For example, in an effort to document and understand students’ CT processes as they designed interactive media, Brennan and Resnick (2012) described three dimensions of CT: (a) computational concepts, such as operators, data, events, sequences, and conditionals; (b) computational practices (e.g., testing and debugging, reusing and remixing, abstracting, and iterating); and (d) computational thinking perspectives (e.g., expressing, connecting, and questioning).

Brennan and Resnick (2012) drew on examples of children and adolescents’ interactive media creation using Scratch, a block-based programming environment similar to Snap! that allows students to design and share interactive media. They argued that CT is a process of thinking and learning that requires deep understanding of the interconnectedness of CT concepts, practices, and perspectives. Rather than being a passive consumer of programming, “a computational thinker sees computation as more than something to consume; computation is something they can use for design and self-expression” (p. 10). Unpacking the interrelated practices of CT and composition can also “offer a broader conception of what ‘writing’ with computers may look like in the 21st century” (Burke & Kafai, 2012, p. 438).

Jacob and Warschauer (2018) developed a three-dimensional theoretical framework for exploring the connections between CT and literacy instruction. This model explored the relationship between CT and literacy through (a) situating CT as a literacy; (b) outlining mechanisms by which students’ existing literacy skills can be leveraged to foster CT; and (c) elaborating ways in which CT skills can facilitate literacy development. This framework considers CT to be a new literacy that is embedded in modern sociocultural practices. These emergent theoretical approaches that propose CT as a literacy practice can allow educators to rethink ways literacy instruction can facilitate CT and, conversely, how students’ existing CT skills can be leveraged to promote literacy development.

Teacher Professional Development

As educators infuse CT into their classrooms, they must participate in and generate new learning paradigms that enable them to integrate learned content with critical thinking, professional quality communication, problem-solving skills, collaboration and group work dynamics, innovation, and creativity (Kivunja, 2015). Research suggests that numerous factors, including participant assumptions, learning style, approach to pedagogy and feedback, and perceived value of the content can negatively impact learning (McNaught et al., 2012; Lee et al., 2013). As such, the theory of adult learning and andragogy (Merriam, 2001) can provide guidance on how adults learn, assignments that facilitate learning, and sequencing of events to promote learning in adults (Harper & Ross, 2011). Andragogy contrasts with pedagogy in that it offers a construct in which responsibility for making decisions about what will be learned does not rest solely with the PD facilitators, but instead the learner becomes active in the learning process rather than a passive participant (Freire et al., 2018).

Complicating the design of effective and meaningful teacher PD even further was the shift to virtual PD models and formats due to the COVID-19 pandemic (Ferdig et al., 2020). Rethinking teacher PD for these virtual and hybrid spaces has required a certain amount of flexibility and grace, as interactions with professionals needed to be virtual, synchronous, brief, and sometimes optional (Bozkurt et al., 2020; Jandrić et al., 2020). The learning environment needs to be organized best to deliver content, monitor progress, provide feedback, and build community (Elliott, 2017).

Last, due to the emotional strain and workload that teachers encountered as part of teaching in a pandemic, a means is needed not only to evaluate but to reward teachers for their participation in the learning events and community (MacIntyre et al., 2020; Panisoara et al., 2020). Despite these challenges, online or virtual learning spaces provide an opportunity for sustainable, disruptive transformation of some of the challenges that permeate teaching and learning in traditional contexts. They also present an opportunity to model and unpack virtual and hybrid learning pedagogies to help teachers adjust to these modes of teaching in their own classrooms.

Rethinking CT PD for virtual and hybrid learning environments provides opportunities to utilize new resources for instruction, organization, evaluation, and feedback in the process of learning (Albert et al., 2020). It also poses new conundrums, particularly regarding scaffolding interactions and building virtual communities to sustain pedagogical innovation and change.

To take ownership of pedagogical practices, teachers need opportunities to adapt strategies and tools according to their experiences, expertise, and classroom contexts. In our study, we were particularly interested in teachers' PD experiences and the ways that they appropriated and adapted pedagogical tools to integrate CT into their classrooms. We defined appropriation as the process by which teachers adopt, use, and modify pedagogical tools and processes that are influenced by both cultural and social contexts (Grossman et al.,1999; Leont'ev, 1981; Vygotsky, 1978; Wertsch, 1991). Grossman et al. (1999) described five degrees of appropriation: (a) lack of appropriation, (b) appropriating labels, (c) appropriating surface features, (d) appropriating conceptual underpinnings, and (e) achieving mastery.

Understanding how individual teachers appropriate pedagogical practices introduced in PD settings can help to unpack the affordances and constraints of PD structures and designs. Grossman et al. (1999), for example, argued that understanding PD requires "attending simultaneously to individuals and the settings in which they learn and develop" (p. 25).

Our work, therefore, had multiple goals: understanding ELA teachers' experiences, unpacking the types of standards and existing pedagogies that they saw as connected to CT, and tracing how teachers with different goals and levels of expertise took up and transformed pedagogical tools for CT infusion. The following section provides information on the context and participants in this study, as well as methods for data collection and analysis.

Method

Context: Infusing Computing

Infusing Computing is the name of a 4-year project designed to support middle and high school teachers in learning to integrate CT into their classrooms. In the initial 3 years, from 2017-2019, more than 250 teachers participated in 1-week workshops held in a face-to-face format, as well as follow-up academic-year activities (Jocius et al., 2020). To ground teachers' understandings of CT and to ensure a common vocabulary among all participants, we defined CT using the mnemonic device PRADA, which defines CT elements (pattern recognition, abstraction, decomposition, and algorithms; Dong et al., 2019) to help teachers see more concrete connections to their disciplinary teaching practices.

We also designed and leveraged the 3C PD model to support educators as they learned to embed CT into their existing curriculum (Jocius et al., 2020). During weeklong summer sessions, participants engaged with CT discourse, pedagogical content knowledge, and concepts related to CS. The model includes three session types: Code, Connect, and Create.

The goal of the Code sessions was to provide participants with opportunities to build understanding of CT principles, learn programming concepts, and gain experience in programming using Snap*!* (Harvey & Mönig, 2010), a programming language similar to Scratch. The goal of the Connect sessions was to reinforce CT concepts outlined in the PRADA model in the context of their respective disciplines. Participants were sorted into Connect sessions based on their content area assignments (ELA, social studies, math, or science) or by self-selection (instructional coaches, world language teachers, etc.).

During Connect sessions, participants engaged in synchronous discussion and asynchronous standards mapping exercises to identify specific content standards, potential connections to CT concepts, and sample classroom activities. The goal of the Create sessions was to reflect with PD participants on their new learning from the two morning sessions (i.e., Code and Connect) and engage in collaborative designing and creating of learning segments that infuse CT into their content area classrooms.

During Create, participants designed CT-infused lessons and teaching artifacts, including slide decks, graphic organizers, and other tools to support the implementation of their lessons.

Infusing Computing: Virtual Pivot

In spring 2020, as the effects of the COVID-19 pandemic shuttered schools and disrupted daily life, our initial plans for the summer 2020 PD needed to change. We decided to shift Infusing Computing to a weeklong virtual conference format (Jocius et al., 2021). To give participants a clear structure for navigating the PD and access to all needed materials, videos, and resources, we used Canvas as the learning management system (LMS). We designed daily Canvas modules, with individual pages for each 3C session. In addition to using Canvas, we utilized Hopin, a video streaming platform with multiple features for networking, social walls, whole-group and small-group chats, and participant direct messaging, to simulate the feel of a face-to-face conference.

Video conference tools like Zoom and Google Meet allowed for virtual meetings between PD participants, but once an event moves beyond 50 people, keeping things organized can be difficult. Hopin is built for events with more than 50 people, as it tries to replicate a physical convention center, concert hall, or PD destination. Participants can explore areas of an event and find the content and people they want to engage with most.

We also adapted introductory sessions, community-building activities, and technical supports for the virtual format. During whole-group sessions at the beginning and end of each day, we engaged in a variety of activities to leverage teachers' existing knowledge to familiarize them with CT principles and ideas. At the beginning of each day, for instance, teachers spent 15-30 minutes connecting to prior experiences, reviewing feedback from the previous day, reflecting on new knowledge, and discussing institutional and contextual factors that shape the ways in which CT is understood and communicated. In addition, we encouraged participants to utilize open-all-day help desks, coding assistance sessions, and Hopin networking features, which offered the chance to meet randomly with a fellow participant in 5-minute sessions.

The constraints of the global pandemic inspired us to think critically and creatively about how best to move forward to offer the best PD experience for participants. Teachers need a careful balance of synchronous activities for learning new content and interacting with colleagues, as well as asynchronous activities that provide time for reflection and practice. In addition to designing collaborative activities with clear outcomes and goals, our PD provided intensive support for engagement with the content and practice. Teachers also participated in a variety of follow-up activities throughout the 2020-2021 academic year, including monthly webinars, which focused on digital badging, virtual and hybrid teaching, short exercises to introduce CT vocabulary to students, and CT assessment.

Participants

Overall, 151 middle and high school content area teachers, including 49 teachers who participated in previous face-to-face Infusing Computing workshops, attended the virtual Infusing Computing workshop in summer 2020. Participants from two Southeastern states were eligible to apply to attend the PD. This article focuses specifically on 27 ELA teacher participants, including eight teachers who were returning Infusing Computing participants. Teachers had an average of 11.5 years of experience, with 14 teachers working in middle school classrooms and 13 working in high school classrooms. In addition to teaching ELA courses, eight teachers taught additional subjects, including social studies, English to speakers of other languages, and technology integration.

Data Analysis

Data analysis was conducted in three phases that aligned with the research questions. To understand teachers' experiences with Infusing Computing (RQ1), we used a mixed methods approach to analyze ELA teachers' pre-PD (n = 27) and post-PD survey responses (n = 25). Pre-PD survey items focused on beliefs and self-efficacy related to CT infusion, goals for professional learning, and teaching experiences. The post-PD survey included additional items related to participants' experiences with Virtual Pivot.

We also utilized the constant comparative method (Glaser & Strauss, 1967) to examine transcripts from semistructured teacher interviews conducted the week after the PD (n = 22), recordings of the ELA Connect sessions, and teacher-created PD artifacts. Interview questions focused on participants' teaching contexts, their experiences with virtual PD, and their Virtual Pivot experiences.

For returning participants, additional questions asked them to reflect on teaching CT-infused lessons and compare the face-to-face PD experience to Virtual Pivot. Teacher-created PD artifacts included responses to discussions, classroom implementation materials, brainstorming documents, and other products created during 3C sessions. To analyze qualitative data, we engaged in recursive cycles of descriptive coding (as recommended by Glaser & Strauss, 1967). Open coding was used to identify emergent themes, and codes were organized into themes and subthemes to identify central phenomena within the data (as recommended by Saldaña, 2015).

To discover the connections teachers identified between CT concepts and ELA standards (RQ2), we analyzed teachers' standards-mapping activities and reflections completed during the first 2 days of Connect sessions. For each standards mapping response (n = 47), we compiled descriptive statistics on the quantity of connections made to each ELA strand and then analyzed and coded each response to determine the most prevalent ELA and CT connections. This approach allowed us to examine which ELA topics and standards teachers saw as connecting most clearly to CT concepts.

To analyze the ways teachers appropriated and adapted pedagogical tools when learning to infuse CT into their ELA classrooms (RQ3), we selected three case studies for more detailed analysis (see Yin, 2017). To unpack teachers' experiences at different points in their developmental trajectories, we chose two teachers who were new to Infusing Computing and a collaborative team of two teachers returning for a 2nd year of PD. The case studies also represent different grade levels (middle and high school).

To triangulate findings across data sources (Patton, 2014), which is one of the hallmarks of case study research (Yin, 2017), we analyzed several data sources, including CT-infused lesson plans, programming products, and other artifacts created during the PD, semistructured interview responses, 6-month follow-up surveys, and reports of classroom lesson implementation (surveys, reflective journals, and videos).

Findings

Findings are divided into three sections that align with the research questions. First is a description of ELA teachers' experiences with Infusing Computing and shifts in their understandings of and beliefs about CT. Next, findings are detailed from an analysis of the standards mapping activity to identify ways teachers connected ELA and CT concepts. Finally, three case studies are analyzed for evidence of ways teachers appropriated and adapted pedagogical tools for CT infusion.

ELA Teachers' Understanding of CT Infusion

Many of the ELA teachers in this study, particularly those who were participating in Infusing Computing for the first time, noted some initial discomfort with the idea of infusing CT into their classrooms. Several new participants said that they were unsure at first whether ELA teachers were even eligible for the program, with one mentioning that "most of the time, we're not included in the technology or STEM PD stuff."

On the pre-PD survey, while returning participants and a minority of new participants defined CT as a thinking process, many new participants referred to CT as coding or the use of technology only. Teachers reported a wide variety of motivations for attending the PD, including "increasing rigor," "engaging students," becoming "more comfortable with implementing technology," and building "cross-curricular lessons." One returning middle school reading teacher said that she loves "implementing CT lessons because they are generally highly engaging, and they help us explicitly teach higher-order thought processes required by our standards."

Examination of the post-PD surveys and interview responses revealed significant shifts in teachers' understanding of CT and beliefs about CT infusion. Overall, ELA teachers reported high levels of engagement with the PD. On a 5-point Likert scale item asking participants to rate the overall effectiveness of the PD, the average score for ELA teachers (*n* = 25) was 4.8, which was slightly higher than the overall average score for all teachers (*n* = 119). In addition, post-PD surveys revealed that teachers reported shifts in beliefs about the importance of integrating computational thinking into ELA teaching, as well as increases in self-efficacy. ELA teachers' average scores were higher in all categories when compared to overall participant scores (see Table 1).

Table 1
Comparison of ELA Teachers' Beliefs Self-Efficacy and PD Rating to Overall Teacher Scores

Post-PD Survey Questions	ELA Teacher Participants (*n* = 25)	All Virtual Pivot Participants (*n* = 119)
I am more likely to incorporate CT activities in my classroom. (1 = *Strongly disagree* to 5 = *Strongly agree*)	4.80	4.65
I can more effectively design CT activities. (1 = *Strongly disagree* to 5 = *Strongly agree*)	4.65	4.52
I can better engage students in making sense of CT and designing solutions to problems. (1 = *Strongly disagree* to 5 = *Strongly agree*)	4.77	4.58
Overall PD Rating (1 = *Poor* to 5 = *Excellent*)	4.81	4.78

Teachers attributed these shifts in understanding to specific elements of the PD, including collaboration with disciplinary colleagues and structured experiences in unpacking links between ELA and CT concepts. Making sense of these CT practices and discourse systems, which involved providing a computer with specific instructions to follow to solve a problem, can pose a challenge for teachers unfamiliar with CT. To address these challenges, collaborative knowledge construction mechanisms effectively helped project participants learn and organize knowledge during the PD experience. For example, Diana, a returning participant, mentioned finding a collaborator during the afternoon Connect sessions:

> She also teaches English and we're like, "Wait a minute, why aren't we creating a project that we can do together? That would benefit the kids." It was just by coincidence. I just found that I'll be teaching ninth grade this year, and so we were like, "That's just crazy. Let's just do something that can be useful, right away." And that's how we did it. So, the collaboration piece was really great.

ELA teachers also described opportunities to interact with disciplinary colleagues in the Connect and Create sessions as being beneficial for their learning. After completing standards mapping activities in the first 2 days of Connect sessions, Day 3 and Day 4 sessions provided opportunities for participants to engage in discourse within a smaller community of fellow ELA teachers. This structure provided teachers with thinking partners to expand on ideas for their lessons and to gather the opinions and thoughts of others teaching the same content. This facilitation occurred in both audiovisual ways and utilizing the chat in individual sessions. These discussions pushed teachers' thinking about their own conceptualizations of CT in the ELA classroom and opportunities to either expand or contract their lesson planning ideas.

For example, during one of the first Connect sessions, Josh, a 1st-year Infusing Computing participant, shared an idea for a lesson focusing on pronoun antecedent agreement that incorporated elements from No Red Ink lessons. Josh described his CT-infused lesson as being "simple enough to feel manageable, but very useful." Other ELA teachers in the Connect session agreed and encouraged his work.

As Josh came to better understand CT and how it could be integrated and leveraged in ELA, he continued to build on the lesson idea. In the following discussion, Ava, the Connect session facilitator (a lead ELA teacher and previous Infusing Computing participant), pushed his thinking about the CT component of his lesson plan.

> Ava: So, what is your PRADA element?
>
> Josh: Oh my gosh, I'll tell you what – I put decomposition because I'm breaking down the different parts, but really, you could have a few different things here. Um, what is my focus? I guess algorithms, because they are recognizing a formula for how to use he, she, they.
>
> Ava: But if the thinking is about recognizing commonalities –
>
> Josh: Oh. It's pattern recognition first then.
>
> Ava: Yes, because you have to ask yourself, what's the work they are doing?
>
> [Josh and other participants nod and indicate nonverbal agreement.]
>
> Ava: You have to separate the work you are doing and what they are having to do.
>
> Josh: Yes, see I'm struggling with that.

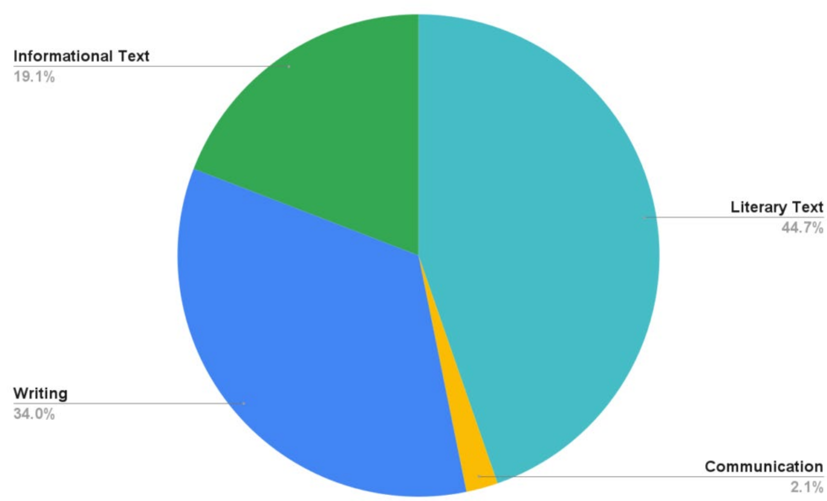
This exchange reveals how Josh's thinking about CT in relation to the pronoun antecedent agreement shifted through dialogue and coaching. Ava pushed his thinking about not only who would be doing the computational thinking in the lesson (him as the teacher versus the students in his classroom experiencing the lesson), but also helped him to recognize the development of his own understanding of how to utilize PRADA elements. Ultimately, Josh decided to focus his lesson on pattern recognition, as he felt that CT concept would best support students' learning as they recognized and applied standard English grammar rules for pronoun antecedent agreement.

Connecting CT Concepts to ELA Practices

During standards mapping in the Connect sessions, participants utilized state ELA standards to crosswalk standards and indicators with CT concepts. They were asked to identify opportunities for CT integration by citing the indicator, unpacking the connection, providing sample classroom activities, evaluating possibilities for plugged or unplugged CT integration, and describing assessment plans. After the standards mapping activities, small groups of teachers talked about the content standards and reflected on opportunities to leverage CT knowledge and skills to support, reinforce, or extend ELA learning targets.

Across both states that participants taught in, there are five major strands for English language arts standards: inquiry-based literacy, reading literary text, reading informational text, writing, and communication. The most frequently mapped strands were reading literary text (n = 21), writing (n = 16), and reading informational text (n = 9), while only one response focused on communication, and no responses focused on inquiry-based literacy (see Figure 1).

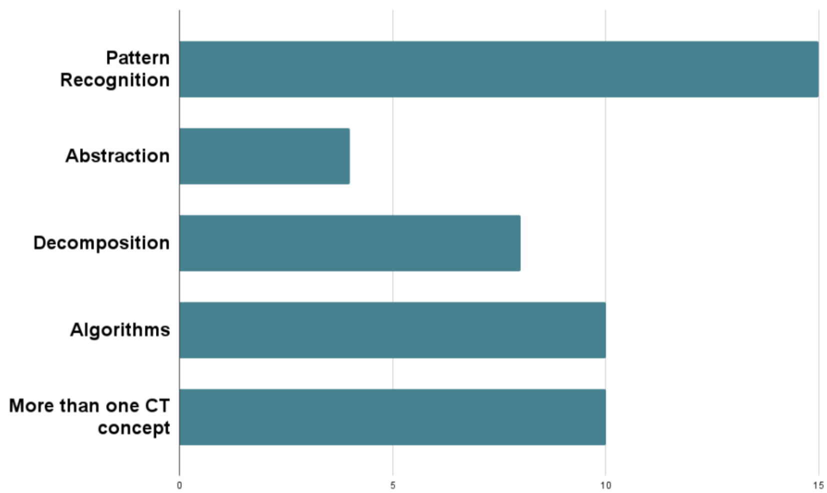
Figure 1
ELA Teachers' Standards-Mapping Responses by Strand



Pattern recognition was most frequently connected to literary analysis, algorithms were most frequently connected to writing standards, and decomposition and abstraction were connected to multiple different strands, standards, and indicators. Further, teachers focused on the major content standards and heavily weighted indicators for all strands (literary text – analysis and theme; informational text – central idea; writing – argumentative). In district and school level curriculum maps, these indicators are typically repeated in multiple units throughout the course of the year. They also build on one another, so that students practice the same skills but at increasing levels of text complexity.

The most frequently identified CT element was pattern recognition (*n* = 15), and the least frequently identified element was abstraction (*n* = 4; Figure 2). As teachers became more familiar with the PRADA elements over the course of the week, several began to link their standards and activities to more than one CT element.

Figure 2
CT Elements in ELA Teachers' Standards-Mapping



For example, Katherine, a high school ELA teacher, described an unplugged lesson in which students would create a list of myth components (decomposition) and then identify common elements (pattern recognition) across different creation myths. As an extension activity, students would compose their own creation myths. Katherine began to see how PRADA elements do not work in isolation but can be combined to allow students to understand how CT concepts overlap and work together. She also noted that students' interest and experiences with creation myths could strengthen student understanding of the PRADA elements and provide a familiar context for supporting understanding of the new CT concepts.

Teachers noted that the use of sentence starters provided in the Code sessions and reinforced in the Connect sessions helped them to unpack the "why" and "how" of the connection to the content. For example, one teacher, Mark, explained how he saw decomposition as connecting with a standard indicator that focused on students' abilities to determine themes and analyze relationships to characters, setting, and plot. Mark explained the connection and the intentional use of decomposition by stating, "In this case, students will need to break down the story into smaller elements that make up the story in order to analyze how they interact." Multiple teachers also utilized the sentence starter element of "hiding the details" when identifying connections between the CT element of abstraction and determining the central idea in a piece of informational text.

Appropriation and Adaptation of Pedagogical Tools for CT Infusion

To trace how teachers learned to infuse CT into their ELA classrooms, we selected three case studies to micro-analyze teachers' appropriation and adaptation of pedagogical tools. To provide multiple perspectives across different time scales, the cases drew on several sources of data: pre- and post-PD surveys, interviews, lesson plans, Snap! products, video recordings of PD sessions, PD artifacts, and lesson implementation journals and surveys.

Appropriating Surface-Level Features: Explicit Scaffolding

Hailey, a high school English teacher with 6 years of teaching experience and a new Infusing Computing participant, was originally encouraged to attend the PD after her principal sent an email about it to the whole staff. She initially thought that she "probably couldn't do that," because she assumed it was designed for STEM teachers. When she started looking through the project website, she "saw people doing like *The Canterbury Tales*." Her primary reason for choosing to attend was the potential to increase student engagement with ELA content: "Anything to help them love English, I'm all for. And they love doing stuff like this."

Hailey referred to herself as a "foreigner" in the land of computational thinking and said that coming into the PD, she was concerned because "especially in English, we just don't work with things like that." While she was initially unsure if students would benefit from CT integration in the ELA classroom, she also indicated being open to experimentation: "That doesn't mean we can't implement it and make English, you know, more exciting."

Throughout the week of the PD, and particularly as Hailey participated in the Connect sessions, she began to see numerous integration opportunities in regard to essay writing. She said that for her "AP English classes, I can definitely see it really strongly in there." Specifically, she felt that abstraction and decomposition were crucial CT concepts that would help students learn to unpack the writing process and the work needed to draft, revise, and edit their compositions. As she said,

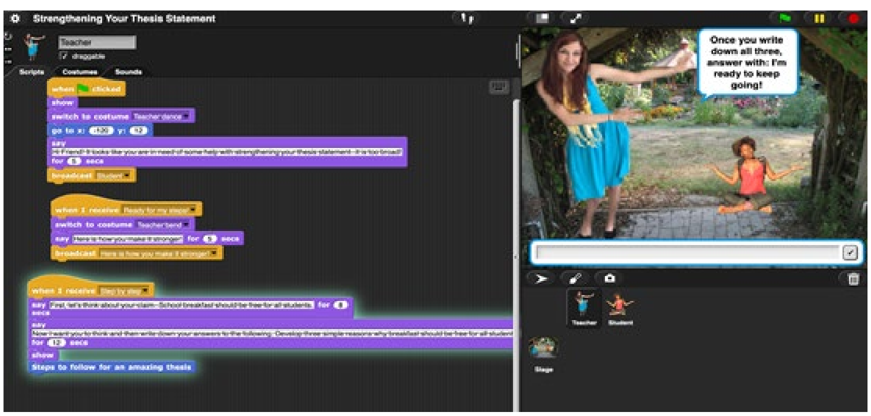
> Taking an essay assignment and instead of jumping into the writing, students must look at pieces (introduction, body paragraphs, conclusion) and learn to break them down first. Getting them to see the abstraction can save a lot of rewriting, headaches, and time!

She also mentioned the idea of counterarguments being related to decomposition: "For instance, in an argumentative essay, if you do not have counterarguments in your body paragraphs or a separate paragraph, you will not have written a successful essay."

When she did standards mapping for algorithms, Hailey identified an ELA standard focused on writing arguments to support claims with clear reasons and relevant evidence. In discussing the content with her Connect group, she noted that she saw inherent connections between the development of claims and the CT concepts of algorithms and if/then statements that could support students' understandings of the ELA content as well as the CT concepts.

During the initial standards mapping, she developed an unplugged activity in which students would follow step-by-step instructions to construct an argumentative essay. Her final lesson, which drew on her work in the Connect session and the standards mapping activities, tasks students with constructing and revising thesis statements using a Snap*!* program. The lesson introduced students to several CT concepts, including decomposition and algorithms, to support the revision process. Students begin by entering their thesis statements into the Snap*!* program Hailey designed. She also created a series of prompting questions to help students ensure that their thesis is specific and aligned with evidence (see Figure 3). As she noted in the lesson plan, there are several "if" and "if/else" statements that support students in breaking down the process of thesis writing in argumentative essays.

Figure 3
Screenshot From Hailey's Argumentative Writing Snap! Lesson



While Hailey said that she was "more knowledgeable" after the PD and that it was "exciting to participate in something outside my comfort zone," she still felt discomfort with the idea of using Snap*!* in the classroom setting. She specifically referenced choosing a structured simulation that she created during the PD rather than a lesson that tasked students with creating their own programs, due to her limited knowledge: "I think I would be super nervous to introduce them to Snap*!* and how to do it. I don't think I'm competent enough quite yet."

Hailey mentioned that the next steps for her own professional growth would be to build differentiated activities for Snap*!* based on student preferences and experiences. She said that while she was uncomfortable with teaching Snap*!* to a whole classroom, she could differentiate learning experiences to provide opportunities for students to become producers of new media: "I'd like to integrate and have them create their own Snap*!* programs for an end-of-unit type project. That could be one of the options for those kiddos that absolutely love that type of thing." In future lessons, she planned to further unpack connections between CT and writing, but to build in more options for students to engage and experiment with coding as part of the process.

Adapting Concepts: Students as Content Creators

Veronica, a new Infusing Computing participant and high school ELA teacher with over 10 years of experience, signed up to attend the PD because she thought it would be "cool." Her primary teaching assignment is to support English learners and she said that before coming into the PD she was uncertain about how CT could be successfully infused into her classroom. Like Hailey, she also expressed some discomfort with the idea of connecting coding to her disciplinary teaching:

> I think once I realized it was coding, I did say, "I have no idea what I'm doing." And I had to quit telling myself that. So, I went in with this expectation of "I don't think I'm going to be able to do this. I don't really see how this is going to help my students" to "Oh, wow, this is actually really neat. I can't wait to try to see how I can maybe use this with my kids."

Throughout the summer PD, Veronica's goals for infusing computing into her classroom shifted. After her first Connect session, she said that her primary goal was to "provide customized, high-quality, assistive exposure to computer science and computational thinking to my English language learners in a safe environment." She mentioned that CT concepts could potentially help to fill in critical gaps for students in terms of their writing abilities.

> I guess probably the most obvious is that in writing, I'm continually trying to teach my students that there really is an algorithm to their writing and they just, you know, for whatever reason, can't hear it. Can't see it. And this will help in using some new vocabulary to kind of teach that."

Veronica expressed some concerns about being able to interact with colleagues within a virtual PD:

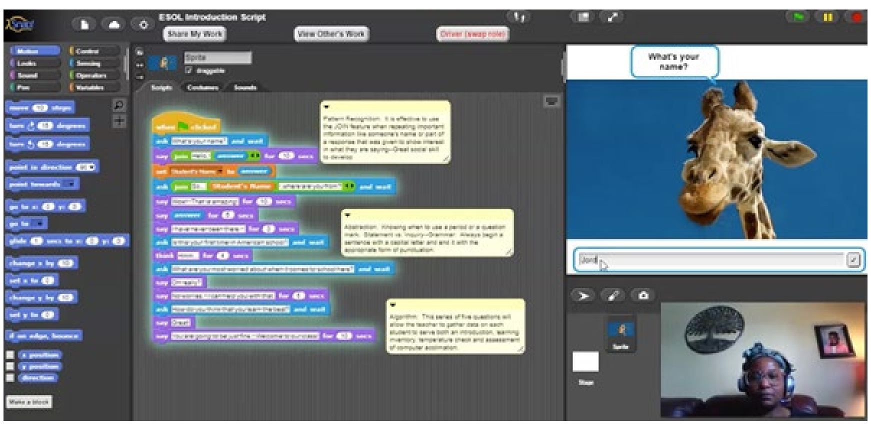
> I am always about learning and meeting new people. That's my two favorite things in the whole world. And so, when it went virtual, I remember thinking, "How am I going to be able to, not only learn but really interact?"

One of the most critical supports throughout the PD was the variety of different types of interaction, including collaborative coding, interactive discussions during Connect sessions, and networking in Hopin. As she said, “As soon as you guys started putting us into partners, I mean, my enthusiasm was just yanked up.”

During the Connect sessions, Veronica connected pattern recognition and abstraction to a lesson goal of using first-person verbs for personal introductions. She designed a minilesson using a gradual release of responsibility (I do, we do, you do) structure for her English learners. She drew on this Connect work to design a lesson focused on supporting students’ abilities to use Snap*!* to create personal narratives.

Her Snap*!* prototype allowed her to introduce herself to her students and included a series of questions to assess students’ language abilities and their understanding of discourse patterns informally. Her program incorporated extra wait time, positive reinforcement, repetition of students’ answers, and personal information about herself, including her love for both giraffes and *Star Trek*. As she said in a director’s cut of her work (see Figure 4), “I basically created what they told me was an algorithm – because I didn’t know that – to ask a series of questions that can be used as an introduction for students in an ESOL classroom.”

Figure 4
Screenshot From Veronica’s Director’s Cut of Her Snap! Introduction Lesson



Her plan also asked students to create their own introductions, a task based on her knowledge of students’ personal and cultural assets, as well as standards-based practices. She said that, since her students struggled with formal presentations, using Snap*!* would allow her students to interact with a sprite and practice using formal English in a low-stakes environment.

To scaffold students’ work, she built in a Parson’s problem, a common computer science task modeled during the Code sessions that provides learners with all the code required to solve a particular problem, but in a scrambled format. Her goal was to have students “piece together their own algorithm of three to five probing questions to extend an introduction conversation based on another person's responses to each question." She also said,

> I am especially excited about using Snap*!* as a computer literacy and English literacy tool, because I have always known how smart my students are even though their spoken English language production is viewed as low or limited by others. The use of Snap*!* will be a safe way for them to showcase those skills with the modern support of a computer.

By the end of the summer PD, Veronica felt confident in her abilities to identify CT elements connected to her disciplinary teaching: "I think I can do a good job of explaining the elements through my field and through simple things like a recipe or just things that I'm really familiar with." She was less confident in her abilities to identify CT elements within programs, however: "I struggled identifying it in code. And then when watching other people's final projects and Snap*!*, I realized, like, I get what it means, but I don't necessarily know how to spot them."

When she implemented elements of her lesson into her classroom, she said that her students were "overwhelmed at the ease of using the computer to 'create' something. Their minds were blown, really." She also referenced regularly using CT vocabulary, including algorithms, "to complete daily and weekly tasks to cement English language acquisition." Veronica also used a digital badging system with her students throughout the 2020-2021 academic year to "reinforce consistent successful work ethic in the hybrid learning classroom." In addition to designing the badges collaboratively with her class using Canva, she used the badges to "acknowledge successful habits of mind for success," and serve as a motivational tool for her students.

One of the areas for future growth that she described was continuing to practice coding and collaborating with colleagues, including computer science teachers, to design and implement interdisciplinary learning experiences for her English learners. Her goal for these experiences was to provide additional experiences with both content-specific learning, as well as CT concepts and discourses.

Mastering Concepts

Rick and Sam, who both teach middle school social studies and ELA classes, attended Infusing Computing PD in summer 2020 and participated in follow-up events, including monthly webinars, throughout the 2019-2020 academic year. For summer 2021, both served as facilitators for the Connect sessions, and as participants for the Code and Create sessions. In reflecting on his 1st year in the program, Rick said, "I'll be honest with you, I showed up last year, just a ball of clay ready to be molded just because I didn't know what in the world we were doing."

Sam said that he was surprised at how useful the training had been and how much it impacted his classroom instruction: "We use it in our classrooms on a regular basis. It makes me a better teacher and it makes me a better leader within my school. I wish every PD that we went to was this practical and this useful."

As a returning participant, Rick said that he felt a responsibility to help other ELA and social studies teachers come to see computational thinking as a thinking process:

> I think I've learned to code to an extent, but this year it was like, "What can I do to be responsible for others?" In the Connect sessions I was always telling people, "Hey, these are some unplugged activities we did, and this is how PRADA has changed our instruction. This is the way we've helped the kids and done unplugged and plugged-in activities." I think it was more about sharing our experience and how it's not just about code. It is about coding. But it's not just about coding. Again, it's about that thought process.

Sam specifically referenced his own learning trajectory and the need for continued participation within the Infusing Computing community: "It's not like you go and you're learning the exact same thing as you did the year before. Every year, you gain more knowledge and you build off what you already have a foundation on."

While both Rick and Sam were initially skeptical that the Infusing Computing virtual conference could replicate the in-person experience, both felt that the virtual environment allowed for consistent and meaningful interactions, particularly in terms of the Code and Connect sessions. As Sam said, "In the Connect sessions before, I do feel like it was a lot easier to hide in the background and kind of take that session off. I felt like participants got more out of that session this time around." Both also felt that supports for engagement and monitoring progress, including networking and badges, were critical to the success of the PD and could be easily adapted for their own classroom teaching. As Rick said,

> We actually stole the badge idea for badges in our Canvas to do this year so that way they [students] can work for something now.... I was skeptical, but those badges were just the best motivation to get us through. It was great motivation. I really liked it.

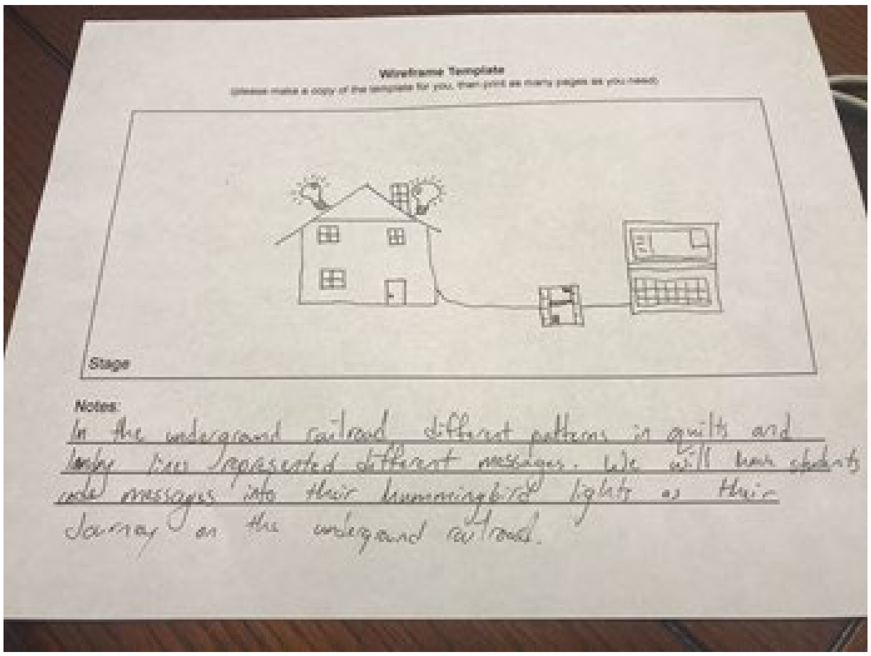
Sam agreed:

> People went nuts over these badges, especially the people in my group. I called them "badgers" because they kept on bugging [the research team] for their badges. Grown adults get excited about badges! Can you imagine what happens with high school and middle school kids?

The lesson Rick and Sam created focused on students' interpretations and understandings of the forms of communication used in the Underground Railroad. As Rick said, the goal was to provide students with "a digital journey on the Underground Railroad." This integrated response activity incorporated both social studies and ELA standards.

Students first read a series of primary and secondary sources documenting the experiences of both slaves and conductors on the Underground Railroad, a series of safe houses leading to the North and Freedom. Students then examined examples of different signals used, including quilts with certain patterns or the placements of candles in windows. Then, students were tasked with coding patterns using different types of lights using Hummingbird boards, which are physical computer boards that allow students to attach LED lights. Students used Snap*!* to code the signals by coding hummingbird lights to send particular signals for movements (see Figure 5 for wireframe).

Figure 5
Wireframe for Rick and Sam's Underground Railroad Lesson



The project incorporated all elements of PRADA. Students used patterns within their code, learned to "hide the details" by abstracting details, decomposed codes for different signals, and used repeated instructions (algorithms) to tell the lights when to flash. It also built in additional skills and practices relevant to CT, including collaborative planning, problem-solving, and pair programming. Rick and Sam planned an adapted lesson for students who were virtual during the 2020-2021 school year and did not have access to the Hummingbird boards. They assigned one of the Code session activities called "draw a square" and tasked students with designing Snap*!* quilt patterns covered.

In their post-PD interviews, rather than specifically focusing on the lesson they created, Rick and Sam emphasized the value of CT in relation to supporting students' abilities to engage and interact with content. Both referred to CT elements regularly in classroom instruction and designed unplugged activities to support student thinking about pattern recognition, abstraction, decomposition, and algorithms in relation to ELA and social studies content. Rick described PRADA as a model for supporting students in breaking down and understanding disciplinary content:

> PRADA is very similar to the scientific method. But it's a scientific method that you can apply to an ELA topic or you can apply to a social studies topic. So, even when we're doing unplugged activities, I think a lot of times we've used PRADA because we're able to look at a social or historical situation and identify what is the problem. How do we break this problem down? Did this problem fix itself?

Sam referenced the need to build community within his school, as well as his work with Rick and their school's technology coordinator to build momentum for infusing computational thinking and coding into the curriculum: "I feel like we're the biggest cheerleaders for coding in general. We go back to our school and we try to get other teachers to implement it."

Discussion

As the COVID-19 pandemic upended most aspects of society, we needed to consider opportunities to pivot to a virtual environment for Infusing Computing. As we considered various approaches, we took time not only to recreate what the PD might look like in a hybrid format, but to reimagine the event from the ground up. We carefully considered the tools, affordances, formats, structures, pedagogical routines, and most importantly, participants' needs and goals, to provide a mentored learning event. Our aim was to focus on the project goals (i.e., infusing CT in content classrooms) and to support educators as they came to understand the role of CT in their own lives and the potential for creating new learning opportunities for students. Path, place, time, and space were all considerations as we built in opportunities to support participants' learning and to assess the impact of the PD across multiple time scales.

Findings from this study demonstrate that ELA teachers were able to leverage learning successfully from virtual PD to understand how CT connects to their existing standards and curriculum. Analysis of post-PD surveys, interviews, and teacher implementation data (RQ1) suggests that ELA teachers saw considerable value in integrating CT and coding into their classrooms, despite some initial discomfort about a mismatch between ELA disciplinary practices and STEM content. As they learned more about CT and came to understand it as a problem-solving process, they were able to make concrete connections to ELA practices and discourses, including the consumption and production of texts using a wide variety of unplugged and plugged tools.

As previous iterations of Infusing Computing had been successful in face-to-face formats, we were initially concerned that switching to an entirely virtual PD experience might limit teachers' learning opportunities and abilities to collaborate and connect. However, findings indicated that Virtual Pivot was more even more successful than the face-to-face version of the PD. Specifically, teachers said that participating in a virtual learning community, engaging with colleagues in asynchronous and synchronous formats, and using digital means for collaboration (help desks, networking, badges, and discussion boards) offered new ways of connecting across space, time, and disciplinary boundaries.

This finding suggests that effective virtual PD is not only possible, but that virtual spaces have specific affordances for enabling reflection and collaboration. Future research that provides a detailed investigation of the impact of virtual PD structures and supports would make a valuable contribution to research and practice.

This study also investigated the ways in which ELA teachers came to understand CT infusion in a discipline-specific context. Our analysis of teachers' standards-mapping responses (RQ2) indicates that teachers were most likely to identify connections between ELA standards and CT in relation to reading literary text and writing. Teachers also tended to focus on standards that build on students' existing knowledge, rather than on standards that introduce new content or concepts to students. This finding indicates that teachers, especially those who are new to CT, may be more comfortable infusing CT when working with familiar content for which students have some background knowledge.

Some teachers also suggested that they saw benefits in using familiar ELA content for supporting students' emergent understandings of CT concepts. As teachers' understanding of CT and the opportunities it affords for meaning-making in ELA became solidified, they began to integrate multiple PRADA elements into their classrooms. For example, in designing an activity for analyzing creation myths, Katherine recognized that students must engage in the process of decomposition first in order to be able to utilize skills for pattern recognition. This approach reinforces ELA-specific content standards that focus on the ways authors of different texts approach similar themes in a literary text with varying literary elements.

In connection with the third research question, we documented how teachers appropriated and adapted pedagogical tools (Grossman et al., 1999) to make sense of the network of pedagogy, social and cultural factors, and other phenomena that impacted participants' ability to profit from the experience. This data allowed us to understand the diverse influences present in the learning environment that impacted levels of appropriation, ranging from a lack of appropriation to mastery, to offer a useful lens for considering how teachers appropriate and adapt pedagogical approaches for CT infusion (see also Kim & Hannafin, 2011; Hurtado et al., 2012).

In our reimagining of the Infusing Computing PD for a virtual environment, we focused on opportunities to foster learner autonomy and different pathways to CT infusion. We found that, while some teachers seem most comfortable in providing highly structured simulations and activities for students to engage in as consumers of content, others aim to provide students with experiences that offer opportunities for students.

For example, Hailey, who viewed CT and coding as a way to engage her students with technology, expressed discomfort with teaching students how to code and, instead, chose to use a highly scaffolded simulation to support students in revising their thesis statements. While she understood some features of CT, particularly as they related to helping students recognize patterns and decompose elements of writing, she appropriated this information at a surface level, rather than leveraging CT to support students in becoming more critical consumers and producers of new media.

Veronica represented a second level of appropriation, the adaptation of concepts. Her lesson, which tasked students with interacting with a model introduction, solving a Parson's problem, and then coding their own Snap*!* introductions, offered students choice and positioned them as producers of content. Her goal was to leverage the introduction activity to assess students' language abilities, support them in interpersonal engagement, and provide an opportunity for them to experience coding. She appropriated the "conceptual underpinnings" (Grossman et al., 1999, p. 18) of CT, including the potential for collaboration and problem-solving using computational tools.

Finally, Rick and Sam, who had participated in prior Infusing Computing workshops, represent a third level of appropriation, the mastery of concepts. Not only did they collaboratively construct a lesson, with Jessica's extension available for students with advanced programming skills, but they built in collaboration as a key lesson component. Further, their lesson on the Underground Railroad also reflects interdisciplinary standards, offering students the opportunity to collaboratively use CT to solve problems that cross disciplinary boundaries. This represents a view of CT as a thought process. Creating meaningful learning experiences is not "just about coding," as Rick put it, but about using computational thinking to engage meaningfully with disciplinary content in ways that also provide exposure to computer science concepts and practices.

Understanding the different pathways teachers may follow as they learn to infuse CT into their classrooms can enable the design of professional learning experiences that support flexible and autonomous engagements with different CT concepts and forms of integration. As we envision the future of CT infusion, our work is expanded by a social, situated, and critical framing of computational thinking (Kafai et al., 2020). As the Internet becomes the dominant text of our generation, an expanded view of education needs to include visual, digital, and other multimodal texts and tools (Dalton, 2012).

Infusing CT into K-12 learning environments, and specifically, into ELA classrooms, provides opportunities for students to read the word and the world (Freire & Macedo, 1987) as they leverage multiliteracies practices and tools (Cope & Kalantzis, 2000). In the Infusing Computing PD, we fostered experience that not only empowered educators but the students in their classrooms as they utilized CT to make meaning and renegotiate identities, practices, and possible futures (as also in Rowsell & Walsh, 2011).

One limitation of our work, and of research on virtual PD more generally, is the long-term impact of these experiences on teachers' beliefs and practices (Kyrakides et al., 2017; Lawless & Pellegrino, 2007). As part of our ongoing work with the Infusing Computing project, we will continue to study how teachers' approaches to infusing CT into their disciplinary teaching change over time. Similarly, studies that focus on the longitudinal impact of virtual PD would allow researchers to investigate the durability of new knowledge and impacts on classroom instruction.

Conclusion

In this study, we examined ELA teachers' experiences in a virtual PD program, shifts in their understanding of CT, and the ways they appropriated and adapted pedagogical tools to infuse CT into their instruction. Given that much of the existing work on CT infusion has focused on the disciplines of science and mathematics (Weintrop et al., 2016), we were particularly interested in examining how ELA teachers came to understand CT in the context of their discipline, as well as how they appropriated and adapted pedagogical tools when infusing CT.

Findings demonstrated that virtual PD can shift ELA teachers' understanding of CT as a tool for supporting students' abilities to consume and produce content and that teachers see specific connections between ELA standards and CT concepts. We also found that teachers' experiences with CT, as well as their teaching contexts and goals, can shape the ways in which they appropriate and adapt pedagogical tools for CT infusion. This work illustrates the potential of virtual teacher learning programs that leverage CT as a tool to support critical consumption and production of texts.

Infusing CT into ELA classrooms can enable teachers and students to dig deeply into why and how computers work and to critique and reimagine digital systems. The challenge is that many educators are not given the education, PD, or latitude to understand how technology can enable that work. Integrating computational thinking into disciplinary teaching offers a potentially critical context for undertaking this work, but PD must be carefully scaffolded to support different learning pathways for teachers with different personal goals, prior experience with CT and computer science, and levels of technological expertise. Our hope is that our work can inform efforts to infuse CT across all content areas, including disciplines (e.g., ELA, social studies, special education, and the arts) that have been understudied in the emergent literature on CT integration.

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References

Achinstein, B. (2002). Conflict amid community: The micropolitics of teacher collaboration. *Teachers College Record*, *104*(3), 421-455.

Albert, J., Jocius, R., Barnes, T., Joshi, D., Catete, V., Robinson, R., O'Byrne, I., & Andrews, A. (2020). Research-based design recommendations for transitioning a computational thinking summer professional development to a virtual format. In R.E. Ferdig, E. Baumgartner, R. Hartshorne, R. Kaplan-Rakowski & C. Mouza (Eds.), *Teaching, technology, and teacher education during the COVID-19 pandemic: Stories from the field* (pp. 59-64). Association for the Advancement of Computing in Education. https://www.learntechlib.org/p/216903/

Bozkurt, A., Jung, I., Xiao, J., Vladimirschi, V., Schuwer, R., Egorov, G., Lambert, S.R., Al-Freih, M., Pete, J., Olcott, D., Rodes, V., Aranciaga, I., Bali, M., Alvarez, A., Roberts, J., Pazurek, A., Raffaghelli, J.E., Panagiotou, N., Coëtlogon, P., … Paskevicius, M. (2020). A global outlook to the interruption of education due to COVID-19 pandemic: Navigating in a time of uncertainty and crisis. *Asian Journal of Distance Education*, *15*(1). https://doi.org/10.5281/zenodo.3878572

Brennan, K., & Resnick, M. (2012). New frameworks for studying and assessing the development of computational thinking**.** *Proceedings of the 2012 annual meeting of the American Educational Research Association, Vancouver, Canada* (Vol. 1, p. 25). AERA.

Burke, Q., & Kafai, Y. B. (2012, February). The writers' workshop for youth programmers: Digital storytelling with scratch in middle school classrooms. *Proceedings of the 43rd ACM Technical Symposium on Computer Science Education* (pp. 433-438). Association for Computing Machinery.

Chan, C. K., & Pang, M.F. (2006). Teacher collaboration in learning communities. *Teaching Education, 17*(1), 1-5.

Chang, Y. H., & Peterson, L. (2018). Pre-service teachers' perceptions of computational thinking. *Journal of Technology and Teacher Education*, *26*(3), 353-374.

Cope, B., & Kalantzis, M. (1999). *Multiliteracies: Literacy learning and the design of social futures*. Taylor and Francis.

Cropley, D. H. (2015). Promoting creativity and innovation in engineering education. *Psychology of Aesthetics, Creativity, and the Arts*, *9*(2), 161.

Dalton, B. (2012). Multimodal composition and the common core state standards. *The Reading Teacher*, *66*(4), 333-339.

Dong, Y., Cateté, V., Jocius, R., Lytle, N., Barnes, T. Albert, J., Joshi, D., Robinson, R., &

Andrews, A. (2019). PRADA: A practical model for integrating computational thinking in K-12 education. *Proceedings of the 50th ACM Technical Symposium on Computer Science Education* (pp. 906-912). Association of Computing Machinery.

Elliott, J. C. (2017). The evolution from traditional to online professional development: A review. *Journal of Digital Learning in Teacher Education*, *33*(3), 114-125.

Ferdig, R. E., Baumgartner, E., Hartshorne, R., Kaplan-Rakowski, R., & Mouza, C. (Eds.). (2020). *Teaching, technology, and teacher education during the COVID-19 pandemic: Stories from the field*. Association for the Advancement of Computing in Education.

Freire, P., & Macedo, D. (1987). *Literacy: Reading the word and the world*. Bergin & Garvey.

Freire, P., Macedo, D., Koike, D., Oliveira, A., & Freire, A. M. A. (2018). *Teachers as cultural workers: Letters to those who dare teach*. Routledge.

Glaser, B.G., & Strauss, A.L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Aldine De Gruyter.

Grossman, P. L., Smagorinsky, P., & Valencia, S. (1999). Appropriating tools for teaching English: A theoretical framework for research on learning to teach. *American Journal of Education*, *108*(1), 1-29.

Grover, S., & Pea, R. (2013). Computational thinking in K–12: A review of the state of the field. *Educational Researcher*, *42*(1), 38-43.

Harper, L., & Ross, J. (2011). An application of Knowles' theories of adult education to an undergraduate interdisciplinary studies degree program. *The Journal of Continuing Higher Education*, *59*(3), 161-166.

Harvey, B., & Mönig, J. (2010). Bringing "no ceiling" to Scratch: Can one language serve kids and computer scientists. *Constructionism*, 1-10. https://bjc.berkeley.edu/documents/2010%20Constructionism%20-%20Bringing%20No%20Ceiling%20to%20Scratch%20-%20Can%20One%20Language%20Serve%20Kids%20and%20Computer%20Scientists.pdf

Hestness, E., Ketelhut, D. J., McGinnis, J. R., & Plane, J. (2018). Professional knowledge building within an elementary teacher professional development experience on computational thinking in science education. *Journal of Technology and Teacher Education*, *26*(3), 411-435.

Hurtado, S., Alvarez, C. L., Guillermo-Wann, C., Cuellar, M., & Arellano, L. (2012). A model for diverse learning environments. In M. B. Paulsen (Ed.), *Higher education: Handbook of theory and research* (pp. 41-122). Springer.

Israel, M., Pearson, J. N., Tapia, T., Wherfel, Q. M., & Reese, G. (2015). Supporting all learners in school-wide computational thinking: A cross-case qualitative analysis. *Computers & Education*, *82*, 263-279.

Jacob, S. R., & Warschauer, M. (2018). Computational thinking and literacy. *Journal of Computer Science Integration*, *1*(1). https://doi.org/10.26716/jcsi.2018.01.1.1

Jandrić, P., Hayes, D., Truelove, I., Levinson, P., Mayo, P., Ryberg, T., Monzo, L. D., Allen, Q., Stewart, P. A., Carr, P. R., Jackson, L., Bridges, S., Escano, C., Grauslund, D., Manero, J., Lukoko, H. O., Bryant, P., Fuentes Martinez, A., Gibbons, A., ... Hayes, S. (2020). Teaching in the age of Covid-19. *Postdigital Science and Education*, *2*(3), 1069-1230.

Jocius, R., Joshi, D., Dong, Y., Catete, V., Robinson, R., Barnes, T., Albert, J., & Lytle, N. (2020). Code, connect, create: The 3C model for integrating computational thinking into content area classrooms. *Proceedings of the 50th ACM Technical Symposium on Computer Science Education* (pp. 971-977). Association of Computing Machinery.

Jocius, R., Albert, J., Joshi, D., Dong, Y., Catete, V., Robinson, R., Barnes, T., Albert, J., & Lytle, N. (2021). The virtual pivot: Transitioning computational thinking PD for middle and high school content area teachers. *Proceedings of the 51st ACM Technical Symposium on Computer Science Education* (pp. 1198-1204). Association of Computing Machinery.

Kafai, Y., Proctor, C., & Lui, D. (2020). From theory bias to theory dialogue: Embracing cognitive, situated, and critical framings of computational thinking in K-12 CS education. *ACM Inroads*, *11*(1), 44-53.

Kim, M. C., & Hannafin, M. J. (2011). Scaffolding problem solving in technology-enhanced learning environments (TELEs): Bridging research and theory with practice. *Computers & Education*, *56*(2), 403-417.

Kivunja, C. (2015). Unpacking the information, media, and technology skills domain of the new learning paradigm. *International Journal of Higher Education*, *4*(1), 166-181.

Knowles, M. S., Holton III, E. F., & Swanson, R. A. (2014). *The adult learner: The definitive classic in adult education and human resource development*. Routledge.

Kyriakides, L., Christoforidou, M., Panayiotou, A., & Creemers, B. P. M. (2017). The impact of a three-year teacher professional development course on quality of teaching: Strengths and limitations of the dynamic approach. *European Journal of Teacher Education, 40*(4), 465-486.

Labbo, L. D., & Reinking, D. (1999). Negotiating the multiple realities of technology in literacy research and instruction. *Reading Research Quarterly*, *34*(4), 478-492.

Lawless, K. A., & Pellegrino, J. W. (2007). Professional development in integrating technology into teaching and learning: Knowns, unknowns, and ways to pursue better questions and answers. *Review of Educational Research, 77*(4), 575-614.

Lee, Y., Choi, J., & Kim, T. (2013). Discriminating factors between completers of and dropouts from online learning courses. *British Journal of Educational Technology*, *44*(2), 328-337.

Leont'ev, A. (1981). *Problems of the development of mind*. Progress.

Li, Y., Schoenfeld, A. H., diSessa, A. A., Graesser, A. C., Benson, L. C., English, L. D., & Duschl, R. A. (2020). Computational thinking is more about thinking than computing. *Journal for STEM Education Research*, *3*. https://dx.doi.org/10.1007%2Fs41979-020-00030-2

Love, K. (2009). Literacy pedagogical content knowledge in secondary teacher education: Reflecting on oral language and learning across the disciplines. *Language and Education*, *23*(6), 541-560.

MacIntyre, P. D., Gregersen, T., & Mercer, S. (2020). Language teachers' coping strategies during the Covid-19 conversion to online teaching: Correlations with stress, wellbeing and negative emotions. *System*, *94*, 102352.

McNaught, C., Lam, P., & Cheng, K. F. (2012). Investigating relationships between features of learning designs and student learning outcomes. *Educational Technology Research and Development*, *60*(2), 271-286.

Merriam, S. B. (2001). Andragogy and self-directed learning: Pillars of adult learning theory. *New Directions for Adult and Continuing Education*, *2001*(89), 3.

Panisoara, I. O., Lazar, I., Panisoara, G., Chirca, R., & Ursu, A. S. (2020). Motivation and continuance intention towards online instruction among teachers during the COVID-19 pandemic: The mediating effect of burnout and technostress. *International Journal of Environmental Research and Public Health*, *17*(21), 8002.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books.

Patton, M. Q. (2014). *Qualitative research and evaluation methods: Integrating theory and practice* (4th ed.). Sage.

Rowsell, J., & Walsh, M. (2011). Rethinking literacy education in new times: Multimodality, multiliteracies, and new literacies. *Brock Education Journal, 21*, 53-62.

Saldaña, J. (2015). *The coding manual for qualitative researchers*. Sage.

Shute, V. J., Sun, C., & Asbell-Clarke, J. (2017). Demystifying computational thinking. *Educational Research Review*, *22*, 142-158.

Smith, B. E., & Shen, J. (2017). Scaffolding digital literacies for disciplinary learning: Adolescents collaboratively composing multimodal science fictions. *Journal of Adolescent & Adult Literacy*, *61*(1), 85-90.

Vygotsky, L. (1986). *Thought and language* (2nd ed.). MIT Press.

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education and Technology*, *25*(1), 127-147.

Wertsch, J. V. (1998). *Mind as action*. Oxford University Press.

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33-35.

Yadav, A., Good, J., Voogt, J., & Fisser, P. (2017). Computational thinking as an emerging competence domain. In *Competence-based vocational and professional education* (pp. 1051-1067). Springer. Yin, R. K. (2017). *Case study research and applications: Design and methods*. Sage.