ABSTRACT

BOULDEN, DANIELLE MARIE CADIEUX. Building the Capacity of In-Service Teachers to Integrate and Teach Computational Thinking. (Under the direction of Dr. Kevin Oliver).

The integration of computational thinking (CT) and computer science (CS) into formal K-12 learning experiences are critical for students to be competent 21st Century problem solvers. Building student competency with these areas is dependent upon educators who have the pedagogical content expertise to integrate CT and CS within their disciplines and impact student learning in the classroom. Thus, as new K-12 CS standards are established, we must ensure that teachers have appropriate resources and support structures that will enable them to meet these new curricular demands. The purpose of this research was to offer practical and scholarly contributions that would support K-12 non-CS teachers' CT integration practices. Thus, two separate but related studies were conducted.

Despite a growing recognition that K-12 teachers should be prepared to teach students CT skills across disciplines, there is a lack of valid instrumentation measuring teachers' teaching efficacy beliefs to do so. The first study addresses this problem by developing and validating an instrument that measures in-service teachers' beliefs for teaching CT. The instrument is grounded in Bandura's theory of self-efficacy and the sub-constructs of personal teaching efficacy beliefs and outcome expectancy teaching beliefs. The manuscript reports on the development and validation process which included expert review, cognitive interviews, factor analysis and reliability calculations. The results indicated that the T-STEM CT is a theoretically sound and reliable instrument to measure in-service teachers' self-efficacy for teaching CT. Implications are then discussed of how the validated, theoretically-grounded instrument can further future research on how to prepare current K-12 educators to teach CT.

The second study investigated how a cohort of educators at one middle school collectively enacted new leadership roles to promote the school-wide integration of CT and CS through programming. Using an instrumental case study approach, this investigation examined how leadership was distributed as a distinct activity amongst these educators as they worked to promote these innovative pedagogical practices within the culture of the school. Distributed leadership was utilized as the guiding theoretical lens and activity theory as an evaluative lens to determine how these educators coordinated internal and external resources, collegial relationships, and their own professional capabilities to build a collaborative, professional learning environment focused on CT/CS integration across the school curriculum. Data were collected through observations of and interviews with members of the leadership cohort and other school faculty. The findings suggest that a collective and distributed approach to leadership allowed these educators to effectively pool resources that cultivated and built support for this important school-wide professional learning initiative. This research has implications for the integration of CT and CS in the K-12 curriculum, as many states have recently adopted CS education standards and are seeking successful integration models at the school and district levels.

Building the Capacity of In-Service Teachers to Integrate and Teach Computational Thinking
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by
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DEDICATION

This dissertation is dedicated to my family; without your understanding, support, and encouragement, this would not have been possible.

BIOGRAPHY

Danielle Cadieux Boulden was born in Exeter, N.H. where she grew up with her parents and older sister. She is a proud first-generation college student who was encouraged by her family at an early age to pursue post-secondary education so that she could achieve opportunities that had not been afforded to them. This encouragement instilled a life-long love and passion for learning. Danielle spent many long hours as a young child teaching her stuffed animals and dolls their ABCs on the chalkboard in her bedroom. Not surprisingly, she pursued a career in education and received a Bachelor of Science degree in Education from Plymouth State University in 2000 and moved to North Carolina to pursue her childhood dream of becoming a teacher.

Danielle received a Master's degree in Education from East Carolina University in 2005 in Instructional Technology and worked as a school technology facilitator and school media coordinator. In these roles, Danielle discovered her passion for helping students and teachers use technology to enhance teaching and learning. While enrolled in the doctoral program at North Carolina State University, Danielle worked at the Friday Institute for Educational Innovation, where she was afforded opportunities to continue working with students and teachers through the research and development of innovative technology projects. Danielle's research interests are undergirded by a commitment to providing equitable access to computing and technology for all students. Danielle is currently a Research Scientist at the Center for Educational Informatics at North Carolina State University where she continues to work on developing transformative learning technologies. She lives with her husband, two children, dog, cat, and turtle.

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Chapter One: Introduction

Advancements in technologies and computing over the past few decades have drastically altered the world in which we live. In fact, many argue that the *Digital Age* and *Information Age* eras have now been supplanted by the *Innovation Age* (Johnson, 2018; Sakai-Miller, 2016; Satell, 2018). This new era has been characterized as one in which individuals will be expected to capitalize on “the infinite power of quantum computing, information access, and connectivity to create the innovations that will drive our future,” (Johnson, 2018, p. 333).

New technologies such as supercomputers, machine learning algorithms, artificial intelligence, augmented reality, and robotics are increasingly changing the professional practices of a variety of industries. As a result of these vast transformations, the required skill sets for occupations worldwide will shift dramatically. It is even estimated that 60-375 million individuals globally may have to change occupational categories as currently existing jobs are displaced by automation (Manyika et al., 2017). These new types of occupations will require a much higher level of proficiency with technology that goes beyond basic digital literacy with information and communication technologies (ICT), as individuals must learn how to navigate and capitalize on the benefits of human-machine collaboration (Sanford & Naidu, 2016).

Simultaneously, our personal lives are becoming dependent upon frequent interactions with various computer programs and software as we navigate realms such as ubiquitous mobile computing, cloud technology, and the internet of things (World Economic Forum, 2018). Thus, successful participation and true empowerment in today’s society requires that individuals are adept at operating and managing these technological resources to take full advantage of their capabilities (NRC, 2011). Likewise, for equitable access to knowledge and information, people must have the skills to mine and analyze the infinite amounts of data that is immediately available at their fingertips. In short, as computing increasingly infiltrates and becomes pervasive in all fields and facets of modern life (Grover & Pea, 2013; Barr & Stephenson, 2011), what constitutes substantial economic and societal participation in today's world is shifting. Individuals must have the skills to leverage the functionalities of these technologies to solve complex problems (NRC, 2011; Rushkoff, 2010; Satell, 2018).

To position current and future generations to be successful in today's economy and society, it is critical that students are equipped with the necessary knowledge and skill sets that afford them with a sound understanding of how computing systems work, how to troubleshoot, and how to apply the technologies to practical problems to derive at effective solutions (Angeli et al., 2016; NRC, 2010, Wing 2006). Essentially to be 21st Century problem solvers, students must learn to go beyond being mere consumers of technology who are proficient with computer use to possessing the ability to utilize computing technology to create and produce computational artifacts (Angeli et al., 2016; Czerkawski, 2015). These demands have spurred recent discussions amongst educators, researchers, and policymakers alike on how to best prepare young people for these changes (Grover & Pea, 2013; Shute et al., 2017). In particular, there is a keen interest in the affordances that the field of computer science (CS) may offer for preparing students with the skills to navigate and manipulate complex computing systems. Many argue that as a discipline, CS offers individuals unique problem-solving strategies that capitalize on logical and algorithmic thinking. These skills equip individuals with the capacity to become innovators and producers with technology rather than consumers (Angeli et al., 2016; Burke et al., 2016; Mannila et al., 2014; Papert, 1991; Sneider et al., 2014).

Recently, much attention has been drawn to the potential value that early exposure to computational thinking (CT) practices could offer students for building foundational knowledge that would allow them to acquire more advanced abilities with CS as they progress through schooling and transition into the modern workforce. Computational thinking is broadly defined as thought processes that are based on CS concepts such as abstraction and composition that allow individuals to formulate and solve problems by leveraging the capabilities of computers (Wing, 2006, 2011).

Statement of Problem

Despite recent efforts to broaden student participation in CS and CT practices (e.g., The White House, Office of the Press Secretary, 2016), opportunities to learn these skills are still largely only offered through highly specialized and self-selective processes (Buffum et al., 2016; Mannila et al., 2014; Margolis et al., 2008). Many of the provisions for engaging in CT and CS practices is only afforded through high school elective courses, often advanced placement, or as part of their participation in out-of-school environments (Lee et al., 2011; Repenning, 2012). Thus, a large majority of students are never exposed to these practices and therefore, miss out on the opportunity to develop early interests and skills that could position them for future academic success in CS and STEM fields (Margolis et al., 2008; Webb et al., 2017). This is a particularly important concern for student populations that have been historically under-represented in fields like CS and STEM (e.g., females, African-Americans, Hispanic/Latinx). Even if students don't choose to pursue CS or STEM-related careers, they are still at a disadvantage from their peers who have been privileged with exposure, as they are left unaware of the affordances that CT and CS may offer them for problem-solving in other domains (Mannila et al., 2014; Sanford & Naidu, 2017; Shute et al., 2017; Yadav et al., 2014). Never has there been a more critical juncture to ensure that all students are provided with robust opportunities to learn these practices.

It is argued that the most effective and equitable way for students to acquire these skills, is by having CT and CS fully integrated into the K-12 curriculum across all content domains and grade levels (Mannilla et al., 2014; Mishra et al., 2013; Lu & Fletcher, 2009; Guzdial, 2008). First, when CT and CS practices are integrated into core content that is part of a compulsory education, all students can gain access and exposure to CT and CS knowledge, thus mitigating problems such as self-selection and social biases (Mannila et al., 2014; Weintrop et al., 2015). Secondly, early exposure can be critical for not only building a solid foundation for embarking on a progression of more advanced skills (Barr & Stephenson, 2011; Lu & Fletcher, 2009; Wing, 2008), but also to capture the motivations and interests of young students (Settle et al., 2012; Yadav et al., 2014). Third, integration across K-12 can help schools and districts who lack the resources (e.g., qualified teachers, lack of funding) to offer stand-alone CS or CT courses (Kale et al., 2018b; Yadav et al., 2016b). Additionally, integrating CT and CS across domains can make learning CT or CS more authentic and meaningful than stand-alone computing courses (Israel et al., 2015). Finally, CT is argued to be a cognitive skill of value to all disciplines (Mishra et al., 2013; NRC, 2010; Voogt et al., 2015).

There are, however, many noted challenges to integrating CT and CS into the K-12 mainstream curriculum. The first set of challenges are institutional and policy-related barriers that plague schools and districts. For example, after surveying principals and superintendents nationwide, Google and Gallup (2016) reported a lack of qualified teachers, the funding and resources to train teachers, and testing mandates in other curriculum areas as some of the most frequently cited obstacles to CT and CS student exposure. Some of the qualitative literature corroborates these findings and simultaneously notes other common barriers such as a lack of access to adequate technology, administrative buy-in, and readily-available curriculum materials

(Adler & Kim, 2018; Boulden et al., 2018; Israel et al., 2015). However, these types of infrastructure and contextual challenges are only one facet of the adversities that have hindered large-scale K-12 CT and CS integration to date.

The role that a teacher has in enhancing student content knowledge and competence in any subject domain is paramount (ISTE, 2019). By integrating CT into classroom learning experiences and modeling those skills and practices for students, teachers can support their abilities to utilize computational ideas and strategies to solve problems in core content areas (ISTE, 2019; NRC, 2010). Unfortunately, many teachers lack a sound understanding of CT and CS and do not have the pedagogical content knowledge to effectively implement CT/CS activities within their disciplines (Adler & Kim, 2018; Shute et al., 2017). Thus, for students to effectively learn CT and CS as a part of their K-12 learning experience, all content area and grade level teachers need to be positioned with the skills and knowledge to teach and model these practices for their students (NRC, 2010; Voogt et al., 2015). In addition, it is critical that teachers have favorable beliefs and attitudes towards teaching CT content so they are prepared to navigate the potential institutional barriers that they may face (Angeli et al., 2016; Israel et al., 2015). Given the current demand for CT integration in K-12 education is still relatively recent, there is still much to be learned about how teachers engage in and respond to recent efforts and initiatives to answer this call (Israel et al., 2015; Voogt et al., 2015; Yadav et al., 2014).

Recent research suggests that well-designed interventions, from structured online courses to even short two-day workshops, can influence teacher attitudes, beliefs, and knowledge about integrating computing, as well as their classroom practices with CT and CS (Kong & Lao, 2019; Ordonez Franco et al., 2018; Pokorny & White, 2012). Although many argue that such interventions are essential to equipping K-12 core content teachers with the capacity to successfully integrate CT in mainstream curriculum (Barr & Stephenson, 2011; Settle et al., 2012; Wolz et al., 2011), the majority of documented interventions are designed for high school teachers who teach CS. Less is known about effective interventions that are best suited for K-12 non-CS teachers to help them develop more favorable perceptions of the value of CT and their abilities to integrate it within their regular classroom practices (Yadav et al., 2014). Furthermore, to properly design and determine the effectiveness of these interventions, it is critical that there are widely available tools to assess teacher competency and attitudes toward CT. Given that this is a new area of interest, there has yet to be a widely accepted validated instrument to be used for this purpose. Additionally, Israel et al. (2015) suggest that researchers continue to investigate how various professional development approaches can help teachers to overcome certain integration barriers such as teacher knowledge, student-level factors, and technology access.

Context of Research

This research has evolved from my prior professional experiences, both as a practitioner and as a researcher. Working in K-12 schools as a technology facilitator, and then a school media coordinator, I had the responsibility of helping teachers to integrate technology into their classroom instruction. Despite providing formal professional development, as well as informal, on-the-job training, many of the teachers were reluctant to have students use technology to develop higher-order thinking skills such as problem-solving and content creation. Instead, the technology that was most frequently used with students was drill-and-practice software or Internet search engines for information retrieval. Often times, the teachers that needed the most assistance were those who lacked confidence with the technology and how to integrate it effectively into instruction.

During my doctoral studies, I began working on research projects that were dependent upon teachers who integrated CT and CS practices into science instruction. I witnessed the same phenomenon that I had as a practitioner; teachers lacked the confidence with the technology and the pedagogical content knowledge to effectively integrate CT and CS. Now in the role of a researcher, I became motivated to investigate approaches that would enable teachers to develop the skills and confidence to provide computationally-rich learning experiences for their students.

In particular, my work on the EcoCS grant (Wiebe, 2018-2021) provided me with an opportunity to coalesce this motivation into distinct research ideas that would be of interest to both the technology and computer science education communities. The EcoCS grant (Wiebe, 2018-2021) utilizes a research-practice partnership to establish a school ecosystem that provides opportunities for all students to learn CT and CS. This work includes collaboratively building the long-term capacity of school staff to integrate CT and computing into their core curricula. To meet this objective, we needed a professional learning structure that included lead teachers to serve as in-house expertise who could support their colleagues as they learned to integrate computing within their teaching practices.

Thus, the grant project became a unique opportunity to study how this in-house expertise could be developed through a team of lead teachers, as well as how they create a professional learning environment for the entire school staff. In particular, I sought to use distributed leadership as a framework to conceptualize the various leadership practices adopted by this team. However, given the complexity of school environment, applying cultural historical activity theory (CHAT) as an analytical lens enabled a more nuanced understanding of the contextual factors that influenced their practices.

Likewise, the grant work necessitated the use of instruments to measure project outcomes, including the teachers' self-efficacy for teaching CT. After being unable to find an existing instrument to meet our research needs, I became motivated to develop a validated instrument that would serve this purpose. The EcoCS project work again became an opportunity to further project goals and offer a potential contribution to the research community by developing an instrument inspired by the T-STEM (Rachmatullah et al., 2019) to measure teacher self-efficacy for teaching CT.

Purpose of Research

The purpose of the research studies that comprise this dissertation was to address the aforementioned sparsity in the current literature base. This goal was accomplished through the execution of two separate but related studies. The first of which was to develop and ascertain evidence of reliability and validity on an instrument to measure teacher self-efficacy for teaching students CT. The second study investigated how a core group of educators at one middle school collectively lead a professional learning initiative on computing integration within their school.

Each of these separate studies addressed the following research questions and sub questions:

Study 1

1) Does the T-STEM CT instrument demonstrate evidence of reliability and validity?

2) What is the internal structure of the T-STEM CT?

Study 2

1) How do a team of educators at one middle school collectively lead a professional learning initiative on computing integration within their school?

1A: How are leadership practices distributed amongst the team and within the larger school context?

1B: What aspects of the situation (context) enable or constrain the leadership practices?

Significance of the Research

With the critical necessity to engage all students in CT and CS practices well before high school, providing support to all K-12 content area teachers to become competent in integrating these practices becomes a concurrent need. However, the field of research concerned with CT integration in K-12 non-CS specific content areas is still in its nascent stages (Grover & Pea, 2013; Israel et al., 2015; Voogt et al., 2015). In particular, as CT and CS practices increasingly find their way into classrooms beyond CS and other specialized computing classes, more empirical research is needed to specifically investigate how teachers develop the capacity to infuse these learning skills in their instruction so that we can ensure they are well-positioned for the task (Mannila et al., 2014; Yadav et al., 2014). Both of these studies independently provided a unique contribution to these ongoing research efforts by offering results that inform both researcher and practitioner knowledge to advance the field.

The purpose of the first study was to develop, validate, and establish reliability on an instrument to measure in-service teacher self-efficacy in regard to teaching students CT skills and practices. There is still much to be learned about teacher efficacy beliefs with CT instructional practices, and a widely accepted, validated instrument that would measure teacher self-efficacy with CT practices will help to forward this area of research. Given that this is a new area of interest, there are very few instruments available for this purpose. In particular, the ability to consistently assess teachers' self-efficacy levels with CT practices can help to inform the design of professional development initiatives and curricular materials for teacher use, allow researchers to synthesize and draw conclusions from results across various studies, as well as to enable practitioners the ability to appropriately assess the effectiveness of such interventions.

The second study more specifically addressed the concern of finding effective interventions that equip non-CS teachers with the skills necessary to integrate CT within their classrooms. By exploring how a cohort of educators at one school enacted new leadership roles to promote the school-wide integration of computing through a professional learning initiative, the study offers a potential model that allows teachers to learn CT integration locally alongside their peers. This research has implications for the integration of CT and CS in the K-12 curriculum, as many states are in the process of adopting CS education standards and looking for effective methods for teacher professional learning and integration at the school and district levels. Moreover, the in-depth qualitative analysis applied through the lens of activity theory provides a holistic understanding of effective leadership actions as they unfold within a school context.

In summary, this research attempted to fulfill gaps in the research by developing a much-needed instrument to assess teacher attitudes for teaching CT in the classroom. Additionally, it utilized an instrumental case study approach to investigate how one school instantiated a school-wide professional learning initiative by developing the leadership capacities of a cadre of educators to guide their peers' computing integration efforts.

Definition of Terms

Computational Thinking

While most trace the conceptual understanding of CT back to the work of Seymour Papert (1980, 1993) during his design and research on the Logo programming environment, Jeannette Wing (2006) is credited with igniting a renewed interest in the idea within the academic community (Angeli et al., 2016; Selby & Woolard, 2013). In her seminal piece "Computational Thinking," Wing (2006) situates CT as rooted in the field of CS, and further defined and characterized it as human thought processes for analyzing and solving problems by applying key constructs from CS such as algorithms, abstraction, automation, decomposition, recursion and modularity. In succeeding publications Wing (2008, 2011) emphasized that engaging in CT does not necessarily require a machine, but rather entails the human mind representing problems and solutions "in a form that can be effectively carried out by an information-processing agent."

Although there is still no one consensus definition to be widely accepted by the academic community, there are many agreed-upon elements and characteristics of the term (Angeli et al., 2016; Selby & Woolard, 2013; Shute et al., 2017). Selby and Woolard (2013) underscored "consensus terms" that have been consistently used by the field to characterize CT to include a thought process, abstraction, and decomposition. They also proposed the inclusion of the following additional terms based on their reoccurrence in the literature: algorithmic thinking, evaluation, and generalization. Likewise, ISTE and CSTA (2011) devised and published an "operational definition" that would be more amenable to application in K-12 education contexts. In this definition, they emphasized CT as a problem-solving process with essential characteristics (i.e., formulating problems in a way that enables us to use a computer and other tools to help solve them; logically organizing and analyzing data; representing data through abstractions such as models and simulations; automating solutions through algorithmic thinking; identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources; generalizes and transferring the problem-solving process to a wide variety of problems). They add dispositions and attitudes that support these skills: “confidence dealing with complexity, persistence in working with difficult problems, tolerance for ambiguity, ability to deal with open-ended problems, ability to communicate and work with others to achieve a common goal or solution.”

Computer Science

The K-12 Computer Science Framework (2016) characterizes CS as the “foundation for all computing” and borrows upon a definition proposed by Tucker et al. (2006) as “the study of computers and algorithmic processes, including their principles, their hardware and software designs, their applications, and their impact on society” (p. 6). Furthermore, the K-12 Computer Science Framework makes a clear distinction between CS and related concepts such as computer literacy, educational technology, digital citizenship, and information technology. The delineation is described as a focus of CS on “why and how computers work” rather than the mere use of computer technologies (K-12 Computer Science Framework, 2016, p. 13). This more profound knowledge then enables a greater understanding of computer use, applications, and related ethics.

Cultural Historical Activity Theory (CHAT)

Cultural-Historical Activity Theory or CHAT is a psychological and multidisciplinary theory that applies a naturalistic emphasis to understanding human activity by integrating individual and social processes (Engeström, 1987/2015, 2001). With CHAT, an activity itself is the unit of analysis and all components within that activity system are analyzed collectively to gain a better understanding of each component (Engeström, 1987/2015; Leon’tev, 1974).
The first generation of CHAT emerged in the 1920s from the work of Vygotsky, who argued that an individual’s actions should not be studied decontextualized from their daily lives, but rather should be considered within a triadic system of how one’s actions towards a goal are mediated

by tools or symbols that are found within their environment (Engeström, 1987/2015, 2001; Vygotsky, 1978). Leont'ev expanded on Vygotsky's ideas to argue that the analysis of human activity should also be considered as a systemic and collective unit that is situated within one's societal and social relations as they strive to achieve an object that drives the motivation for the activity (Engeström, 1987/2015, 2001; Leont'ev, 1974, 1981).

Engeström expanded on Vygotsky's and Leon'tev's work to include a more cultural and historical perspective with the second generation of CHAT by including community, rules, and division of labor into the unit of analysis to account for the collective nature of activity (Engeström, 1987/2015). Engeström's version of CHAT accounts for the context of where an individual's actions take place and how those actions are simultaneously influenced by the different components of the activity system (Engeström, 1987/2015, 2001). Engeström argues that an activity reaches an expansive learning cycle of transformation when a community addresses tensions and contradictions within the activity itself or with competing activity systems (Engeström, 1987/2015, 2001).

Distributed Leadership

Distributed leadership has often been used as a theoretical lens by researchers to better understand the critical role that teachers play in school leadership practices (Harris, 2013; Sebastian et al., 2016; Wenner & Campbell, 2017). While school leadership has historically focused on the practices of those at the top of the organization such as the principal (Harris, 2013), distributed leadership offers an alternative lens to view leadership practice in schools as stretched across those in both formal and informal roles such as teachers (Spillane et al., 2004; Spillane & Orlina, 2005). Distributed leadership rests on the following assumptions: effective school leadership requires multiple leaders; leadership practice occurs through the interactions of leaders, followers, and the context of their situation; and, the situation mediates the leadership practice and simultaneously becomes defined and redefined through that practice (Gronn, 2000; Spillane, 2006). With a distributed perspective of leadership, the unit of interest becomes the leadership activity as it is constituted in the collective interaction of leaders, followers, and their situation as they engage in leadership tasks (Spillane et al., 2004). Distributed leadership acknowledges that teachers play key roles in school leadership, as they offer expertise and assistance with key leadership functions that administrators are not able to execute on their own (Spillane, 2006).

Central to a distributed leadership framework is elucidating how various aspects of the situation such as tools and routines facilitate, constrain, and give shape to practice (Gronn, 2002; Spillane, 2006). According to Spillane et al. (2003), these tools influence how leaders approach and enact tasks. With a distributed leadership perspective, relations among various leadership practices are also considered to examine how various leaders work together or independently on tasks and how that work impacts the leadership activity under study. Thus, understanding these interactions and interrelationships in the larger context of which the practice takes place is key (Spillane & Orlina, 2005). Spillane (2006) defines leadership as activities that are intentionally designed by teachers and administrators to influence the “motivation, knowledge, affect, and practices” of others towards key organizational work that is tied to the school’s core efforts.

Self- Efficacy

Albert Bandura (1997) defined self-efficacy as an individual’s judgment of the degree of capability that they possess that is needed to perform a task or action in pursuit of a desired goal. Bandura’s (1977, 1997) theory of self-efficacy includes the sub-constructs of personal efficacy and outcome expectancy. According to Bandura (1997), an individual’s belief that they possess the ability to effectively accomplish a task (personal efficacy) and the belief that execution of the task will achieve the desired outcomes that they expect it to (outcome expectancy) motivates their behavior.

T-STEM

The T-STEM is an instrument designed to measure teacher efficacy for teaching the various STEM domains (science, technology, engineering, mathematics). Thus, the T-STEM is comprised of four separate subscales that can be administered individually as stand-alone instruments, or together as a collective battery of assessments. The T-STEM was inspired by the Science Teacher Efficacy Belief Instrument (STEBI-A), an instrument widely used by the science education research community for several decades (Cakiroglu et al., 2012; Enochs & Riggs, 1990). Like its predecessor, the STEBI-A, the T-STEM is theoretically grounded in Bandura’s (1997) conceptualization of self-efficacy as two distinct sub-constructs, personal efficacy and outcome expectancy. Thus, each subscale of the T-STEM is comprised of items that measure these two distinct sub-constructs. The T-STEM was designed to address concerns about the STEBI that has been documented by researchers over the years such as a lack of correlation between the subscales (Lekhu, 2013), and its use of outdated language that emphasizes student achievement rather than student growth (Rachmatullah et al., 2019; Unfried et al., 2014). Recent validation work on the T-STEM has established it as a theoretically sound and stable instrument (Rachmatullah et al., 2019).

Chapter Two: Literature Review

Computational thinking has been deemed as a set of critical 21st Century skills and practices that all young learners should be afforded with the opportunity to develop (Wing, 2006; NRC, 2010). Early exposure through core classroom learning experiences is seen as an integral component to ensuring all students are equally prepared to become proficient and innovative creators of new technologies (Qualls & Sherrell, 2010; Thomas et al., 2019). The key to providing K-12 students with the computationally rich learning experiences that are necessary to become proficient computational thinkers is dependent upon a teaching force that has the knowledge, skills, and dispositions to design and deliver appropriate instruction (Barr & Stephenson, 2011; Voogt et al., 2015). However, prior research has found that non-computing teachers face a myriad of challenges in trying to integrate CT skills and practices within their classrooms (Kale et al., 2018a; Yadav et al., 2018).

The purpose of this literature review is to outline the broader conceptual foundations around CT integration that undergird this research. In particular, the synthesis provides an overview of the extant literature on the affective and contextual challenges that influence teacher implementation of CT practices within their classroom learning environments. Considering that research on CT integration is relatively new, I begin by framing the discussion around the various intrinsic and extrinsic factors as it has been conceptualized in the broader technology integration literature. This is followed by a literature synthesis that focuses exclusively on what has been learned about this phenomenon when applied specifically to published studies that address CT integration. Finally, I present cultural-historical activity theory as a guiding theoretical framework and how it relates to the various intrinsic and extrinsic factors that have been found to influence the integration of CT.

Technology Integration Factors

Teachers are seen as integral to the decision of whether or not technology is used within their classrooms; however, teachers' decisions and practices are influenced by a variety of factors including internal characteristics unique to each teacher and those that are externally present within their teaching environment (Hsu & Kuan, 2013; Hur et al., 2016; Li & Choi, 2013). Decades of research has illuminated various intrinsic and extrinsic factors that influence teachers' integration with technology for teaching and learning (Bauer & Kenton, 2005; Ertmer et al., 2015; Gilakjani, 2013; Lawless & Pellegrino, 2007). These variables can be considered as either enablers or barriers to a teacher's technology integration practices (Ertmer et al., 2015; Hew & Brush, 2007).

Intrinsic Factors

Intrinsic factors are often labeled or described as teacher-related variables or characteristics that affect a teacher's decision or ability to integrate technology into their regular teaching practices (Hur et al., 2016; Liu et al., 2016). Intrinsic factors can be demographic characteristics such as age, gender, years of teaching experience, and education level or they can refer to a teacher's affective and cognitive states such as their skills, knowledge, attitudes, beliefs, and confidence (Buabeng-Andoh, 2012; Ertmer & Ottenbreit-Leftwich, 2013; Inan & Lowther, 2010).

Extrinsic Factors

Extrinsic factors that affect teacher technology integration are considered enablers and barriers that are external to the teacher such as access to resources, adequate training and professional development opportunities, technical support, and time for planning and implementation (Ertmer et al., 2012; Hew & Brush, 2007; Inan & Lowther, 2010; Miranda &

Russell, 2012). Individual teachers work and refine their practice within a unique school context that has its own characteristics and infrastructure that should be evaluated when considering how a teacher uses technology within his or her classroom (Donnelly et al., 2011; Lim et al., 2013; Vrasidas, 2015). These extrinsic factors are often categorized and investigated as school-level variables by researchers and have been found to have a significant influence on an individual teacher's classroom technology practices. For example, using a multilevel path analysis model, Liu et al. (2016) found that school-level factors accounted for 51% of the variance in teachers' technology use, 21% of technology integration, and 11% of their confidence and comfort using technology.

Literature Search

To conduct this literature review, searches in the following electronic databases were employed: Education Resources Information Center (ERIC), the Association for Computing Machinery (ACM) Digital Library, and Google Scholar. The phrase "computational thinking" and the keyword "teachers" were used in combination and set to be found in any field. The parameter peer-reviewed and limitation of published within the last twelve years were applied given the currency of the topic after Wing's 2006 seminal article. Abstracts were then reviewed for each result to determine if the paper focused on the integration of CT in core K-12 academic areas, rather than afterschool clubs or specialized learning environments, and whether or not it focused on the role of the teacher instead of student outcomes. Additionally, as various articles were selected and read, other articles of interest that were referenced in those works were accessed and reviewed. A strong preference was given to articles that reported on empirically-based research studies and those that focused on in-service teachers.

Computational Thinking Literature Synthesis

Applying the inclusion and exclusion criteria described above, fifty-four articles were reviewed as a result of this literature search to seek specifically for those that investigated factors that influenced teachers' CT integration efforts. The literature synthesis below focuses on the various intrinsic and extrinsic factors that have emerged from the CT integration literature, as well as their influences on teacher CT integration practices.

Intrinsic Factors and Teacher Computational Thinking Integration

The intrinsic or teacher-level factors addressed in these studies can be delineated into cognitive and affective categories. Thus, the broader technology integration literature is much more expansive regarding various intrinsic factors that influence teachers' integration practices in comparison to the more recent literature base on the integration of CT. For example, the broader technology integration literature has historically also included variables of interest such as age, gender, and teaching experience which appears to be mainly absent from the CT-focused integration literature. Table 2.1 provides an overview of the intrinsic factors covered by the studies in this literature review and example citations.

Table 2.1

Intrinsic Factors and Representative Literature

Intrinsic Factors	Example Article Citations
Cognitive	
Knowledge of CT	Bower et al., 2017; Cateté et al., 2018; Corradini et al., 2017; Duncan et al., 2017; Garvin et al., 2019; Kale et al., 2018a; Ouyang et al., 2018; Pollock et al., 2017; Sands et al., 2018; Sentance & Csizmadia, 2017; Yadav et al., 2016a; Yadav et al., 2018.
Skills with CT Tools	Boulden et al., 2018; Cateté et al., 2018; Israel et al., 2015; Kale et al., 2018a; Ouyang et al., 2018; Pollock et al., 2017; Sentance & Csizmadia, 2017; Yadav et al., 2016a
Pedagogical Content Knowledge	Cateté et al., 2018; Repenning et al., 2015; Sentance & Csizmadia, 2017; Thomas et al, 2019; Yadav et al., 2018
Affective (Comfort, Confidence)	Boulden et al., 2018; Curzon et al., 2014; Duncan et al., 2017; Pollock et al., 2017

Cognitive Variables

Teacher-level cognitive factors discussed in the literature can be partitioned into the following three domains: 1) content knowledge of CT as a construct, 2) skills with CT technological tools such as programming, robotics, or data visualization tools, or 3) pedagogical content knowledge of how to support student learning of CT skills and practices. Collectively, these aforementioned cognitive characteristics were much more frequently cited as intrinsic barriers to successful CT integration in comparison to any of the affective factors.

Knowledge of CT. Many of these studies revealed that despite the growing awareness of the value of learning to think computationally, teachers still lack a sound and comprehensive understanding of what CT is (Corradini et al., 2017; Duncan et al., 2017; Garvin et al., 2019). A few of the studies aimed to measure teachers' conceptual understanding of CT. Collectively these studies' results demonstrate that teachers had significant misconceptions with CT as a construct (Bower et al., 2017; Corradini et al., 2017; Garvin et al., 2019; Yadav et al., 2018). In particular, many of these studies found that teachers often equated CT practices to the general use of technology and technology applications. This is problematic given that the mere use of technology prohibits a deeper understanding of how to use computers to solve complex, authentic problems. Therefore, if not corrected, teachers could think they were integrating CT within their classroom practices but in actuality were only providing students with opportunities to engage in basic ICT practices. This exemplifies a need for stronger teacher guidance in the development of much more nuanced definitions of CT, especially of how it is applied within their disciplinary areas.

Skills with CT Tools. Teachers' lack of proficiency with tools that develop students' CT abilities such as programming was a frequently cited barrier in some of the articles reviewed. Programming is increasingly becoming a popular means for fostering students' CT competence (Grover, 2019); however, most of the teachers surveyed in these studies indicated that they had little to no prior programming experience (Cateté et al., 2018; Israel et al., 2015; Yadav et al., 2016a). Therefore, teachers expressed a concern that their lack of expertise in this area was a major obstacle that they had to contend with (e.g., Boulden et al., 2018; Pollock et al., 2017; Sentance & Csizmadia, 2017). This concern was elaborated on by teachers in a study by Pollock et al. (2017), who indicated that they had difficulty keeping up with the students who learned programming skills at a much faster pace.

Pedagogical Content Knowledge. Relatedly, another common theme in addition to teachers' demonstrated or expressed lack of CT content knowledge or CT tools, was a lack of the ability to support students as they learned CT practices. In particular, teachers did not have the skills to be facilitators of learning in these types of environments (Cateté et al., 2018; Repenning et al., 2015; Thomas et al., 2019). Israel et al. (2015) found that once teachers learned that they did not have to be the experts in the classroom and became more comfortable learning alongside the students, they were able to more successfully integrate CT into their teaching practices. This is supported by the larger technology integration literature, which asserts that student-centered learning approaches that position teachers as facilitators are more conducive to optimal levels of student learning with technologies (An & Reigegluth, 2011; Kim et al., 2013). Other pedagogical concerns were illuminated by Sentance and Csizmadia (2017) where teachers expressed concerns of how to differentiate for varied student learning needs, and how to support students' development of problem-solving strategies and persistence.

Affective Factors

In comparison to the larger corpus of technology integration literature that has investigated affective traits, the CT integration literature has a proportionally smaller number of articles that address teacher affective variables. The affective traits that are referenced within these studies are also often not clearly defined or operationalized. The variables discussed in the studies included for this literature review were general attitudes such as teacher comfort, confidence, and self-efficacy (e.g., Cateté et al., 2018; Ouyang et al., 2018; Jaipal-Jamani & Angeli, 2017). Teachers' pedagogical beliefs were not studied in any of these articles and appear to be largely absent from the CT integration literature.

What these studies do demonstrate is that teachers lack confidence and comfort with CT tools. In particular, many teachers specifically noted that because they lacked prior programming experience, they were not entirely comfortable teaching students CT through coding (Boulden et al., 2018; Cateté et al., 2018; Israel et al., 2015). Duncan et al. (2017) also found that teacher confidence with delivering CT-infused lessons depended upon the particular CT or CS topic those lessons addressed, as teachers' reported levels of confidence throughout the year differed with each particular lesson focus.

Not surprisingly other studies noted that teachers' prior level of experience with CT integration influences the confidence in their ability to effectively integrate those concepts into their instructional practices (Garvin et al., 2019; Ouyang et al., 2018). Corradini et al. (2017) suggest that teacher comfort with developing student CT competence is related to the depth of their conceptions of CT. Collectively, these studies suggest that developing teachers' capacity to conceptualize CT, CT practices fully, and CT integration within their disciplines are all integral for teachers to develop the basic affective beliefs that they are capable of doing so. This further supports the importance of well-designed interventions as Israel et al. (2015) found that once teachers realized they had the necessary supports available to them, they became more comfortable with their practices. Likewise, Ouyang et al. (2018) found that although a small sample size (N = 21), teachers who participated in a yearlong professional development that offered them extended supports significantly increased their confidence to design, carry out, and evaluate CT-integrated lessons.

Unfortunately, of the few studies that have specifically addressed teacher attitudes with CT or CT integration, many of them have been conducted with populations of pre-service teachers (Bower & Falkner, 2015; Gadanidis et al., 2017; Yadav et al., 2011; Yadav et al., 2014). Although pre-service teachers are an important population to be concerned with for the development of self-efficacy for teaching CT, given that there are approximately 3.1 million current public school teachers in the U.S. alone (NCES, 2019), we must extend this research to the in-service teacher population as well.

Extrinsic Factors and Teacher Computational Thinking Integration

Sixteen of the articles that were a part of this literature review positioned extrinsic factors as barriers to CT integration or conversely, as supports that were necessary for successful implementation. Those extrinsic factors could be parsed into the following ten categories: Student-related Concerns, Curriculum Constraints, Time to Plan and Learn, Technology Access, Technical Support, Training, and Professional Development, School-level Expertise, Administrative Support, Curricula Resources, Peer Networks. Below in Table 2.2, each factor is listed by the relative frequency with which it appeared in the literature.

Table 2.2

Extrinsic Factors and Representative Literature

Extrinsic Factors	Example Article Citations
Training	Corradini et al., 2017; Garvin et al., 2019; Israel et al., 2015; Kim & Kim, 2018; Sentance & Csizmadia, 2017; Wolz et al., 2011; Yadav et al., 2016a
Administrative Support	Boulden et al., 2018; Guzdial et al., 2014; Heintz & Mannila, 2018; Israel et al., 2015; Kim & Kim, 2018; Pollock et al., 2017; Sentance & Csizmadia, 2017
Curriculum Constraints	Boulden et al., 2018; Guzdial et al., 2014; Israel et al., 2015; Kim & Kim, 2018; Pollock et al., 2017; Settle et al., 2012; Thomas et al., 2019
IT Supports	Boulden et al., 2018; Guzdial et al., 2014; Kale et al., 2018a; Pokorny & White, 2012; Sentance & Csizmadia, 2017; Yadav et al., 2016a
Student-related Concerns	Israel et al., 2015; Pollock et al., 2017; Sentance & Csizmadia, 2017; Settle et al., 2012; Yadav et al., 2016a
Technology Access	Boulden et al., 2018; Israel et al., 2015; Kale et al., 2018a; Morreale et al., 2012; Pollock et al., 2017
Peer Networks	Kim & Kim, 2018; Pollock et al., 2017; Yadav et al., 2016a
Time	Guzdial et al., 2014; Israel et al., 2015; Pokorny & White, 2012

Table 2.2 (continued)

School-level Expertise	Garvin et al., 2019; Israel et al., 2015; Pollock et al., 2017
Resources	Kim & Kim, 2018; Pollock et al., 2017; Sentance & Csizmadia, 2017

Training

Teacher training and professional development needs were one of the most commonly cited extrinsic factors related to teachers' abilities to integrate CT. Although there appears to be a rising number of opportunities for teachers to partake in local training initiatives (Kale et al., 2018a), this is still a salient challenge for concern (e.g., Corradini et al., 2017; Garvin et al., 2019; Yadav et al., 2016a). This is not surprising given that teachers need quality training to build their confidence and knowledge for teaching any discipline (Lawless & Pellegrino, 2007). Recent surveys of teachers in various locations such as South Korea, Italy, Maryland, all revealed that teachers had explicit concerns that a lack of professional learning opportunities hindered their ability to develop their students' competence with CT skills and practices (Corradini et al., 2017; Garvin et al., 2019; Kim & Kim, 2018). In particular, teachers articulated a need for training that focused on enhancing their pedagogical content knowledge (Sentance & Csizmadia, 2017; Yadav et al., 2016a).

Administrative Support

Another recurrent extrinsic factor mentioned in these studies was the critical importance of school-level administrative support and buy-in (Heintz & Mannila, 2018; Kim & Kim, 2018; Pollock et al., 2017). Boulden et al. (2018) found that school leadership was key to motivating teachers at the schools they collaborated with to engage in CT integration efforts. Likewise, Israel et al. (2015) found that by making CT integration a priority, school administration was able to convince teachers to take pedagogical risks despite uncertainty with new performance evaluations. Thus, it is clear that school leadership sets precedence at their schools that are communicated to teachers as the school's priorities and without administrative support teachers are reluctant to engage in new initiatives that are not sanctioned by their administration. Additionally, school leadership can be instrumental in helping teachers ascertain the resources and support that they need to be successful in these endeavors such as secured planning time, technological resources, and necessary support staff (Boulden et al., 2018; Israel et al., 2015; Sentance & Csizmadia, 2017).

Curriculum Constraints

A substantial challenge to CT initiatives is competing curriculum mandates and initiatives. Teachers often cite limited time in the school day to provide opportunities for students to learn CT and that tested subjects and mandated curricula often take priority (Boulden et al., 2018; Guzdial et al., 2014; Israel et al., 2015; Pollock et al., 2017). Similarly, some teachers commented that having dedicated instructional time for all students to practice using tools that are vehicles for fostering CT such as programming and other data visualization tools, would allow a more seamless integration into disciplinary content rather than having to focus on teaching students how to use the technology first (Sentance & Csizmadia, 2017). However, with these competing school priorities, this is often not a reality. Teachers often feel pressure to cover district or state-mandated curriculum content (Boulden et al., 2018; Guzdial et al., 2014) and do not feel like they have the flexibility to deviate when CT is not a mandated subject area. Working with teachers to integrate a CT-infused interdisciplinary unit, Thomas et al. (2019) found teachers experienced the greatest success by having access to a flexible curriculum rather than a rigid curriculum design where teachers had the freedom to adapt the implementation of the materials to their instructional schedules.

Time to Plan and Develop Competence

Studies on CT integration have noted that teachers need dedicated time to create CT integrated lesson plans, as well as the time to develop their competence with CT skills and practices (Guzdial et al., 2014; Israel et al., 2015; Pokorny & White, 2012). In a follow-up survey of K-12 teachers who had attended a CT/CS integration workshop, participants noted that a lack of time to refine lesson plans and develop competence with the workshop materials became major obstacles to implementation (Pokorny & White, 2012). Therefore, any CT-related initiative needs to allocate adequate time as a necessary teacher resource after any related training.

School-level Expertise

Teachers in a study conducted by Israel et al. (2015) remarked that having a school-level expert to provide embedded coaching was particularly useful in the beginning. Other studies have corroborated that teachers find this an important resource beyond initial training (Pollock et al., 2017). Teachers surveyed in a study conducted by Garvin et al. (2019) reported that fellow teachers, media specialists, and technology teachers are most likely to provide this in-house support. Unfortunately, 22.6% of those teachers indicated that they do not have anyone at the school beside themselves to serve as a CT resource (Garvin et al., 2019).

Resources

A lack of curricular materials for immediate use has been an area of concern documented in the literature (Boulden et al., 2018), and those same concerns were echoed by some of the teachers in these studies (Kim & Kim, 2018; Sentance & Csizmadia, 2017; Pollock et al., 2017).

Studies by Kim and Kim (2018) and Pollock et al. (2017) found that teachers noted a lack of available materials for both instructional strategies and content-related resources. Other resource-related challenges were the necessary hardware and software to teach CT content (Sentance & Csizmadia, 2017). Sentance and Csizmadia (2017) also noted that teachers had difficulty evaluating the resources that were available to them.

Technology Access

Despite significant investments and progress made in increasing the availability of technology resources in schools over the past several decades (NESTA, 2012; US Department of Education, 2014), this review revealed that this persists as a relevant obstacle to integrating CT in schools (e.g., Israel et al., 2015; Morreale et al., 2012; Pollock et al, 2017). Boulden et al. (2018) found that issues with outdated technology and incompatible software sapped teacher energy, motivation, time, and resources that were imperative to these initiatives. Yadav et al. (2016a) also reported that because of antiquated computers teachers were not able to run necessary software integral to student learning. Teachers have also noted a lack of funds to buy more expensive technologies that foster CT skills such as robotics and games kits (Kale et al., 2018a).

IT Supports

In a similar vein, having reliable and timely IT support is noted as a factor. Several studies mentioned that CT teaching and learning practices were stalled due to district-wide restrictions on teacher software installation and updates that were necessary to implement the activities (Guzdial et al., 2014; Kale et al., 2018a; Sentance & Csizmadia, 2017). Teachers often lack the administrative privileges to install or update the software on computers and therefore, are at the mercy of district or school-level IT personnel which often precludes student learning opportunities (Guzdial et al., 2014; Pokorny & White, 2012; Yadav et al., 2016a).

Peer Networks

Teachers that are currently integrating computing into their curricula often report feelings of isolation and express a desire to have peer networks with whom they could collaborate and plan with (Pollock et al., 2017; Yadav et al., 2016a). South Korean teachers surveyed by Kim and Kim (2018) reported a desire for access to online communities where teachers could share resources to propagate computing education nationwide. Often school-level professional learning communities are ideal, as Israel et al. (2015) found school-wide CT training became an essential factor of success for a school-focused CT initiative. Thus, CT integration efforts should try to support teachers by providing access to either school-based or online communities of practice.

Student-related Concerns

Other extrinsic factors in this literature review fell under the broader category of student-related concerns that influence teachers' CT instructional practices. Those concerns can be grouped into the categories of student ability concerns, student home access to technology, and student interests. Of these student concerns, the most largely reported by teachers were anxieties about how to address a range of diverse student abilities (Israel et al., 2015; Settle et al., 2012; Pollock et al., 2017; Yadav et al., 2016a).

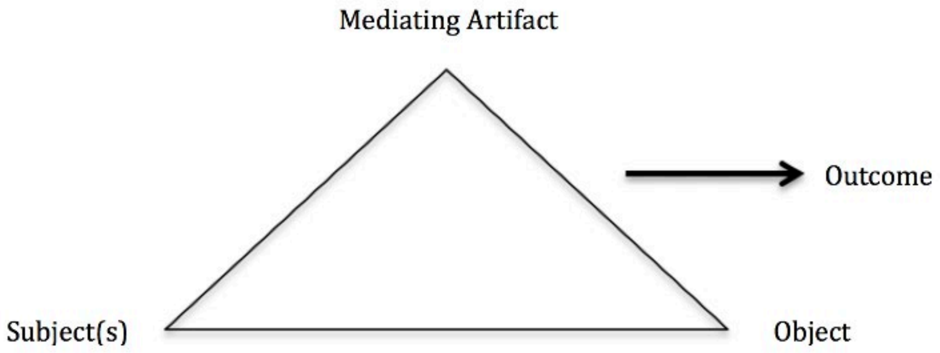
Sentance and Csizmadia (2017) stated that of the five major categories of challenges revealed through a qualitative analysis of UK teachers' survey responses, two were directly related to student concern: student lack of understanding of content and student willingness or ability to solve problems. In particular, teachers described their own pedagogical weaknesses when students were unable to grasp difficult content, how to support the development of their problem-solving skills and build student capacity for persistence and resilience. These findings are supported through evidence from other studies (e.g., Israel et al., 2015; Pollock et al., 2017; Settle et al., 2012), which strongly suggests that teachers need more training on PCK and how to differentiate for varied student learning needs. Teachers have also reported concerns with student access to technology at home as having a perceived impact on their classroom computing initiatives (e.g., Israel et al., 2015; Settle et al., 2012).

Cultural-Historical Activity Theory as a Theoretical and Analytical Lens

Activity Theory is viewed as a multidisciplinary theory that can be applied to study human behavior and social transformation in a wide variety of settings (Barab et al., 2004; Kuutti, 1999). The historical origin of Activity Theory is most notably associated with Russian psychologist Vygotsky as a response to his disillusionment with the behavioral psychology paradigm that dominated his era. This conventional framework depicted human activity as a simple stimulus-response relationship (Vygotsky, 1934/1986, 1978). Vygotsky argued that this simplistic conceptualization did not effectively explain the complex psychological processes of individual human beings (Engeström, 1987/2015, 1999). He alternatively proposed a triangular relationship to exist among an individual subject, the object at which an activity is directed, and a mediating artifact as constituting human activity (Engeström, 1987/2015; Vygotsky, 1978). See Figure 3 for a graphical representation of Vygostky's original model of mediated activity. According to Vygotsky (1978), the objective orientation of action and the mediation of cultural artifacts was the key to understanding individual psychological processes. Vygotsky differentiated between two types of mediating artifacts: technical tools and signs. The former referred to raw materials used by subjects to achieve the object of an activity and the latter are psychological tools such as language, writing, and concepts (Engeström, 1987/2015; Vygostky, 1978).

Figure 2.1

Early Generation Activity Theory Model Based on Vygotsky's Mediated Action

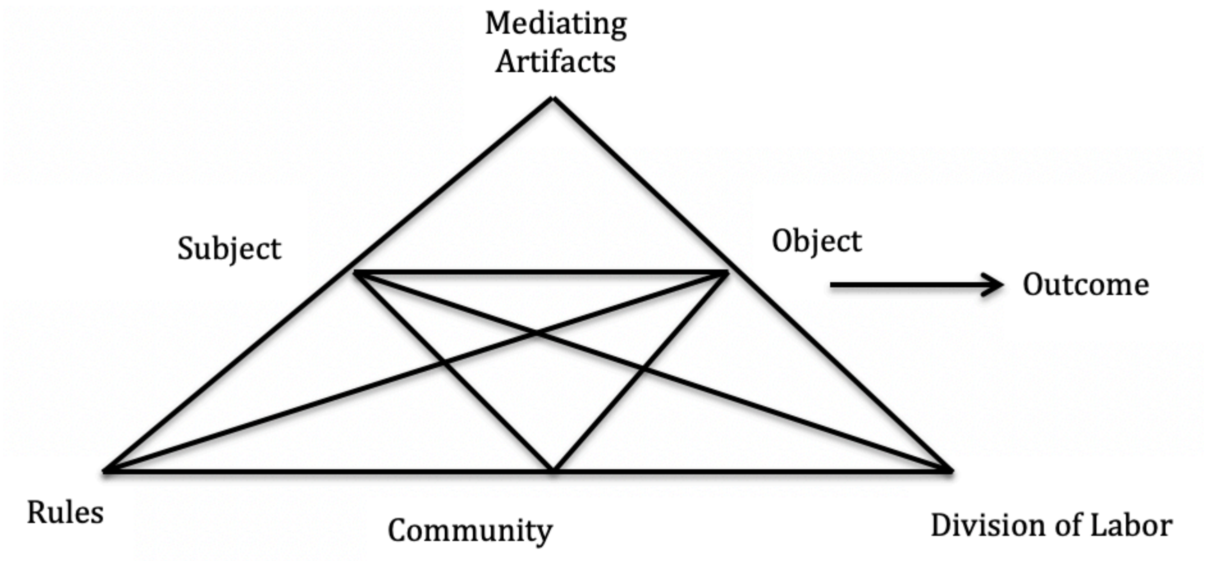


Vygotsky's analysis of human activity was criticized by scholars for its overemphasis on the individual as the unit of analysis (Engeström, 1987/2015). One of Vygotsky's students, A. V. Leont'ev, tried to overcome this limitation by explicitly situating human cognition and behavior within societal social relations by expanding the fundamental unit of analysis from individual to collective activity (Leont'ev, 1974). Thus, Leont'ev, viewed activity as a systemic unit in which subjects were driven by a collective and culturally-derived motive.

CHAT underwent another significant transformation by contributions from the researcher Yrjö Engeström (Ramanair, 2016). As depicted in Figure 5, Engeström (1987/2015) expanded Vygotsky's original activity triangle (e.g., subject, object, tool), to underscore the collective and contextual nature of human activity by adding the components of community, division of labor, and rules. According to Engeström and Sannino (2010), community consists of all individuals and subjects involved in the activity and who share the same object. Division of labor entails how the community divides tasks amongst its subjects horizontally, as well as the inclusion of vertical influences of power within the activity setting (Engeström & Sannino, 2010). Finally, rules reference both explicit and implicit norms and conventions that prescribe actions within the activity system (Engeström & Sannino, 2010). Engeström (1987/2015) developed this new schema to allow for the illumination of contradictions and tensions within the current activity system and with competing activity systems. This conceptualization depicts activity systems as continuously evolving and expanding as solutions to these tensions are resolved and subsequently transform the activity for all participants. It is this dynamic nature of contradictions and tensions both within components of an activity system and between interacting activity systems that helps to characterize this third generation of Activity Theory (Engeström, 2001), where according to Engeström, analysis can now take place "both up and down, outward and inward" (Engeström, 1987/2015, p. xv). Components thus mediate change not only for the object, but also for one another.

Figure 2.2

The Structure of Human Activity According to Engeström (1987/2015)



Engeström has utilized CHAT to analyze human activity and learning in a variety of work, technology, and organizational settings (Engeström, 1987/2015; Engeström, 1999; Engeström, 2001; Sannino et al., 2009). Engeström (1999) argues that the use of CHAT to analyze how individuals learn innovative work practices enables the elucidation of the particular context of that work environment with a focus on understanding the historic, local practices, their objects, mediating tools, and the social organization within the environment.

Analytical Implications of Using CHAT for Research

Utilizing CHAT as a theoretical framework has analytical as well as methodological implications for any researcher who is applying the framework as an analytical lens. First, a particular object-oriented activity setting becomes the basic unit of analysis for the researcher (Engeström, 1987/2015; Kaptelinin & Nardi, 2006; Rasmussen & Ludvigsen, 2009). By expanding the focal point of the analysis to the activity itself rather than individual behavior, this provides the researcher with a framework to conceptualize human action within a larger artifact-mediated collective endeavor that is shaped by the socio-cultural context where it occurs (Engeström, 1987/2015; Kaptelin & Nardi, 2006; Ramanair, 2016; Yamagata-Lynch, 2003). Therefore, individual subjects are still considered to be agents with independent actions; however, it is imperative for the researcher to analyze these actions as mediated by social and material resources within their environment and it becomes critical to pay attention to the logistics of how that mediation occurs (Barab et al., 2004; Ramanair, 2016). Likewise, researchers utilizing an activity theoretical framework must understand that there is a dynamic relationship between the individuals within a particular activity system and the activity system itself, as both elements are simultaneously shaping one another (Kaptelin & Nardi, 2006; Yamagata-Lynch, 2003). This systems-level approach to analysis where each “context-forming” part of the activity system (e.g., subject, object, tools) is taken into account then helps the researcher better understand how individuals negotiate the attainment of particular motives and goals under a variety of sociocultural conditions (Kuutti, 1999; Ramanair, 2016). Engeström's (1987/2015) expanded triangle provides the researcher with a conceptual tool that can aid in identifying, describing, and analyzing each component within an activity system and their dynamic inter-relationships (Barab et al., 2002; Barab et al., 2004; Ramanair, 2016; Rasmussen & Ludvigsen, 2009).

Because of this larger, system-level analysis, the framework is particularly well-suited for studying human activity as it is evolving in real-life contexts (Kaptelin & Nardi, 2006; Ramanair, 2016; Yamagata-Lynch, 2003). The researcher is then able to capture the complexities that surround innovative learning and performance in a variety of institutional settings such as work, schools, and other organizations as events naturally unfold rather than in a controlled environment (Barab et al., 2004; Engeström, 1987/2015; Engeström, 1999; Engeström & Sannino, 2010; Kaptelin & Nardi, 2006). A particular focus of these contexts becomes on how the interactions between the main components of the activity triangle interact and result in a functioning system through observable behavior (Engeström, 1987/2015). This framework aids the researcher in identifying contradictions and tensions that may be present, which either result in unintended less desirable outcomes when not resolved, or conversely can lead to innovative new practices (Engeström, 1999; Lim & Hang, 2003; Sung, 2017). Furthermore, CHAT is not intended to analyze activities in general, but rather is ideal for the analysis of a specific practice that is locally bound with identifiable participants (Cole & Engeström, 1993; Engeström, 1987/2015; Yamagata-Lynch, 2003). Thus, Yamagata-Lynch (2003) suggests that the activity setting determines the participants.

In particular, CHAT is suitable to analyze the development of innovative learning processes and human practices over time (Engeström, 1999), as developmental changes cannot be limited to isolated variables, for different variables and their relationships with one another change over time (Kaptelin & Nardi, 2006). Also, many participant perspectives need to be accounted for since activity development involves multiple participants who hold different perspectives and roles in those environments as they collectively negotiate and orchestrate the coordination of activities (Rasmussen & Ludvigsen, 2009). Subsequently, it is important to note change at multiple levels, as not only is the outcome is a central part of the analysis, but also the individual constituents as they are transformed by the changing conditions (Barab et al., 2004; Rasmussen & Ludvigsen, 2009).

Finally, a key tenet of CHAT is its value to transform practice through research (Sannino et al., 2009). Many scholars argue that a goal of research with CHAT is to promote agency and to enable individuals to work with socio-cultural tools to improve their working conditions (Engeström, 1999; Sannino et al., 2009). Thus, an analytical component becomes how can the results of the research findings be used to generate new concepts, tools, and understandings that can be shared with participants to empower them and equip them with new methods for expanding and transforming real practices in a manner that leads to better solutions and outcomes for those individuals and society at large (Engeström, 1987/2015; Sannino et al., 2009; Engeström & Sannino, 2010).

A CHAT Perspective for Computational Thinking Integration

The various intrinsic and extrinsic factors that have been identified within the literature review in the previous section to influence teacher CT integration efforts can be considered from a CHAT perspective. This section relates the intrinsic and extrinsic factors that appear in Tables 2.1 and 2.2 to the components of CHAT.

Subjects and Object

From this perspective, the teacher becomes the subject whose objective (object) is to effectively integrate CT into their classroom practices. Thus, the teacher (as subject) is influenced by various intrinsic or teacher-level factors that affect their decision or ability to integrate technology into their regular teaching practices (Hur et al., 2016; Liu et al., 2016). Intrinsic factors identified in the CT integration literature include those that can be viewed as both cognitive and affective. The cognitive abilities that are cited include knowledge of CT, skills with CT tools, as well as the pedagogical content knowledge of how to teach CT to students. Additionally, affective dimensions such as one's self-efficacy or interest in teaching and integrating CT are also intrinsic factors that influence a teacher's actions and progress towards integration. The other four components of CHAT (e.g., tools, community, division of labor, rules) can be viewed as the various extrinsic factors that reportedly influence CT integration. It should be noted that because CHAT recognizes the inter-relationships amongst all of these elements (Barab et al., 2004), the extrinsic components will shape these teacher-level variables and vice versa. Therefore, a researcher should account for this complex interplay to fully understand the phenomena (Engeström, 1999).

Tools or Mediating Artifacts

In CHAT, tools are cultural artifacts that mediate the interaction between a subject and the desired object (Engeström, 2001). In the context of teacher CT integration, mediating artifacts would primarily be considered extrinsic factors that are available within a teacher's school environment to help them achieve integration goals. Examples include training or professional learning that helps the subjects build necessary affective and cognitive skills or resources such as technology tools that that teachers can utilize to enhance their CT practices.

Rules

Rules within an activity setting circumscribe a subject's behaviors through accepted conventions or norms within the activity community (Barab et al., 2004). Rules can either constrain or liberate action, depending on the context (Yamagata-Lynch, 2003). Notable examples of rules within the CT integration literature are time and curricular expectations. Many studies have noted that limited time to learn about CT and attend trainings constrain teacher CT integration (Guzdial et al., 2014; Israel et al., 2015). Likewise, state-mandated curricular has also frequently been cited as a barrier to implementation (e.g., Kim & Kim, 2018; Pollock et al., 2017).

Community

The community that comprises a teacher's CT integration activity setting are primarily the students and their colleagues. For example, many authors have recognized student-related concerns as a mediating, extrinsic factor (Sentance & Csizmadia, 2017; Yadav et al., 2016a). Likewise, a teacher's peer network and the amount of school-level expertise are also often cited by teachers as either a facilitating factor or barrier to integration (Garvin et al., 2019; Pollock et al., 2017).

Division of Labor

Division of labor refers to the division of tasks within a community (Engeström & Sannino, 2010). In this regard, the CT integration literature references IT support and support from school administrators as critical extrinsic factors that influence a teacher’s classroom practices.

Summary

In summary, CHAT can help to illustrate the complexity that surrounds the various intrinsic and extrinsic factors that were identified within this literature synthesis. CHAT helps to bring a greater understanding to how the teacher, as an independent agent within a particular setting, is intrinsically influenced by extrinsic factors such as the tools, resources, and collegial support they have access to in the pursuit of a particular goal such as integrating CT. Likewise, CHAT is used as a guiding analytical framework for the research presented in chapter 4.

Chapter Three: T-STEM CT: Measuring In-Service Teacher Self-Efficacy for Teaching Computational Thinking

In 2006, Jeannette Wing published an article arguing that computational thinking (CT) should be a fundamental and customary skill for all students to master before pursuing post-secondary schooling or entering the workforce (Wing, 2006). Wing's appeal has since captured the attention of researchers, policymakers, and practitioners worldwide for compelling reasons (Grover & Pea, 2013; ISTE, 2018). First, the 21st Century has witnessed the growth of a variety of careers and industries that are dependent upon skilled workers who are trained in the use of computationally-intensive tools to solve complex problems (Sanford & Naidu, 2016; World Economic Forum, 2016). Thus, CT has become recognized as a relevant and applicable skill across a variety of disciplines, and not just of value for those in computer science (CS) and computing fields (Henderson, 2009). Furthermore, with the pervasive use of technology and computing in our daily lives (Aho, 2011; World Economic Forum, 2018), CT is seen as an integral 21st Century life skill essential for a successful citizenry. Therefore, it is agreed upon that all individuals, not just those that are privileged, should be able to use technology to make informed decisions and create meaningful products of expression (Angeli et al., 2016; NRC, 2011). As such, since the publication of Wing's influential generative article, many have come to view CT as a critical skill that should be introduced to students early in their formative schooling years (Mannila et al., 2014; Mishra et al., 2013).

Although there is still not a consensus definition (Selby & Woolard, 2013), CT has been broadly defined as a thought process that enables one to formulate problems in a manner that facilitates the use of computers and other tools to derive at efficient solutions (Wing, 2011). Many agree that although teaching CT often involves technology use, it is a skill that does not necessarily require the use of a computer (k12cs.org, 2016; NRC, 2010; Wing, 2008, 2011). With increased attention on CT as a valuable, foundational skill worthy of being taught across K-12 disciplines and contexts (NRC, 2011), important resources have been invested in preparing teachers to teach and integrate CT into their schools and classrooms (Grover & Pea, 2018). The number of states and districts that are offering professional development workshops for in-service teachers is considerably on the rise (Guzdial et al., 2014). Colleges and universities are beginning to add CT and CS courses as graduation requirements to their teacher education programs (Code.org Advocacy Coalition, 2018; Yadav et al., 2014). Moreover, many schools are investing money in technology resources such as robotics kits, programming platforms, and gaming accessories as vehicles for learning CT in school and out of school contexts (Schrum & Summerfield, 2019). Unfortunately, what is not paralleled with these interventions, are robust measures to evaluate whether or not they have resulted in effective teacher outcomes, such as increased teachers' pedagogical knowledge and beliefs towards teaching and integrating CT in the classroom (Davis et al., 2019; Haseski & Ilic, 2019). Without the ability to rigorously assess and document changes in these outcomes, it is difficult to determine whether or not these interventions have been effective. Furthermore, because teachers are the single most crucial factor in determining whether or not students learn these essential skills (ISTE, 2019), evaluating teachers' competency levels for teaching CT becomes imperative.

Prior research on technology integration has found that even though teachers are provided with access to technology and training, it is often teachers' social cognitive beliefs that have the most substantial influence on their practices (Ertmer & Ottenbreit-Leftwich, 2010; Ertmer et al., 2012; Wozney et al., 2006). Self-efficacy, the belief that one has the capability to perform a task (Bandura, 1997), is a theoretical construct that prior research has demonstrated is highly indicative of teachers' pedagogical practices (e.g., Bandura, 1997; Klassen & Tze, 2014; Tschannen-Moran & Woolfolk Hoy, 2001). Therefore, understanding teachers' belief systems, specifically their CT self-efficacy beliefs, is essential for improving teacher practices within this vital domain. Additionally, Ravitz et al. (2017) found that teacher learning outcomes from CS professional development opportunities were influenced by individual teacher characteristics, attitudes, professional environments, and the delivery design of the experience. This suggests a need to tailor CT and CS professional training efforts to teachers' specific needs and contexts. Therefore, a validated instrument that measures teachers' self-efficacy beliefs with teaching CT could be of practical utility to teacher educators and professional developers as they seek to design more effective interventions and then subsequently evaluate those interventions.

This paper contributes to the scholarly literature by developing, validating, and establishing the reliability of a new instrument (T-STEM-CT) to measure K-12 teachers' self-efficacy for teaching CT. The T-STEM-CT is an additional subscale of the Teacher Efficacy and Attitudes towards STEM (T-STEM), which is a validated instrument designed to measure in-service teacher efficacy in the various dimensions of STEM (Rachmatullah et al., 2019). With the growing recognition of computing and CT as cognate domains related to STEM teaching and learning (Hu, 2011), such a subscale could be a welcomed addition for scholars and practitioners involved in STEM-related innovations.

Although some have advocated for a more nuanced definition of CT that addresses specific components such as decomposition, abstraction, algorithms, and debugging (e.g., Selby & Woolard, 2013; Shute et al., 2017), others argue that such a granularity suggests essential and necessary conditions that might only serve to conflate and hinder its mainstream adoption (Guzdial, 2011; Voogt et al., 2015). Furthermore, it is suggested that CT becomes defined within the context in which it is implemented (Hu, 2011; Selby & Woolard, 2013; Voogt et al., 2015). Therefore, this instrument is designed in favor of this broad conception of CT, so that it can be applied and adapted for the context of its intended use, increasing its utility for a wider range of users.

Related Work

A review of the literature and public repositories uncovered very few publications on validated instruments related to assessing teacher knowledge, skills, or beliefs about teaching CT (cf. Haseski & Ilic, 2019). The existing ones primarily targeted teacher knowledge and were designed around specific CS or programming concepts rather than CT more broadly. See Table 1 for a review of published literature that has reported on instruments that were used with teacher populations. For example, Yadav and Berges (2019) validated an instrument to assess high school teachers' CS pedagogical content knowledge. The instrument tasks teachers with reading vignettes and indicating their pedagogical responses to students' various programming misconceptions within those vignettes.

Although the development of a few new validated instruments to assess teachers' CS pedagogical content knowledge is indicative of progress in this area, CT is a distinct construct and is often taught in K-12 contexts without the use of computers or programming. Wing (2006) argued that CT does not necessarily involve the use of a computer, and recently organizations like Code.org have emphasized the value of unplugged activities to teach CT (Code.org, 2020). Therefore, an instrument specifically tailored to teaching CT is of interest to educational researchers and practitioners. Some CT specific surveys have been developed for K-12 teachers, but they tend to focus on assessing teacher knowledge of CT concepts rather than teacher beliefs about teaching CT. For example, Kong and Lao (2019) utilized evidence-centered assessment design to develop items to evaluate teachers' CT practices; however, the items were designed around specific CT constructs such as debugging, abstraction, and algorithmic thinking. Furthermore, they only established internal and test-retest reliability on the instrument as it was administered to a relatively small sample of teachers (N = 80).

Although knowledge and skills are indeed important factors in understanding teacher practices, beliefs and attitudes are also of vital importance as well. Yadav et al. (2011) developed an instrument to assess pre-service teachers' attitudes towards CT, but the instrument largely focused on the students' assessment of their own attitudes towards computing rather than their attitudes towards teaching CT. Garvin et al. (2019) designed the 2018 Maryland Computing Education Landscape Survey to determine how primary teachers in the state conceptualize and integrate CT. Their survey included four items to measure teachers' comfort level with CT integration, and the items demonstrated inter-term reliability; however, their work did not include validation procedures.

Table 3.1

A Review of CS/CT-Related Instruments Used to Survey Teachers

Citation	Target Demographic	Subject(s)	Domain(s)	Validity/Reliability
Bean et al. (2015)	Pre-service teachers as part of intervention lessons	CT as related to programming	Affective	Face validity, Factor analysis, Cronbach's alpha
Bower et al. (2017)	K-8 In-service teachers enrolled in CS4HS workshops	CT	Cognitive, affective	None reported
Cetin (2016)	Preservice teachers receiving Scratch-based instruction	Programming	Affective, cognitive, behavioral	Exploratory and Confirmatory Factor analysis, Cronbach's alpha
Davis et al. (2018)	HS teachers taking PD in CS	CS	Affective	Cronbach's alpha

Table 3.1 (continued)

Garvin et al. (2019)	PreK-8 teachers in MD	CT	Cognitive, affective	Cronbach's alpha
Kong & Lao (2019)	In-service teachers enrolled in teacher development course	CT	Cognitive	Cronbach's alpha
Repenning et al. (2019)	Pre-service teachers as part of a Scalable Game Design course	CS, programming	Affective	None reported
Yadav & Berges (2019)	CS teachers	CS	Cognitive	Item-response theory (Rasch)
Yadav et al. (2011, 2014)	Pre-service teachers as part of intervention lesson	CT & CS	Affective	Cronbach's alpha

Theoretical Framework

Teacher efficacy beliefs have been used as a metric to understand teacher practices for several decades in distinct domains such as science and math (e.g., Enochs & Riggs, 1990; Enochs et al., 2000). According to Bandura (1997), an individual's behavior is motivated by their belief that they possess the ability to effectively accomplish a task (personal efficacy) and the belief that execution of the task will achieve the desired outcomes that they expect it to (outcome expectancy). Therefore, Bandura's (1977, 1997) theory of self-efficacy consists of two sub-constructs: personal efficacy and outcome expectancy. Bandura and Schunk (1981) argued that self-efficacy is task-specific, and thus, instruments to measure teacher efficacy should reflect such contextual specificity rather than global teacher efficacy scales (Wheatley, 2005).

The T-STEM is an instrument that is theoretically grounded in Bandura's (1997) conceptualization of self-efficacy as two distinct sub-constructs, personal efficacy and outcome expectancy, and is designed to measure teacher efficacy for teaching the various STEM domains. The T-STEM was inspired by the Science Teacher Efficacy Belief Instrument (STEBI-A), an instrument widely used by the science education research community for several decades (Cakiroglu et al., 2012; Enochs & Riggs, 1990). The STEBI-A measured self-efficacy with the subscales personal science teaching efficacy (PSTE) and science teacher outcome expectancy (STOE) (Riggs & Enochs, 1990). PSTE measures teachers' beliefs about their own ability to teach science (Riggs, 1988) with items such as "I know the steps to teach science concepts effectively" (Riggs & Enochs, 1990). Whereas the STOE sub-scale was designed to measure a teacher's expectation that their science teaching will have a positive effect on students' learning in science (Riggs, 1988) with items like "Students' achievement in science is directly related to their teacher's effectiveness in science teaching" (Riggs & Enochs, 1990).

The authors of the T-STEM modeled and refined items on the STEBI to develop an instrument that could measure teachers' efficacy and beliefs for teaching each of the STEM domains (science, technology, engineering, mathematics). See Tables 1 and 2 for the T-STEM personal technology efficacy belief items and the teaching outcome expectancy items respectively. The T-STEM addresses concerns about the STEBI that has been documented by researchers over the years such as a lack of correlation between the subscales (Lekhu, 2013), and its use of outdated language that emphasizes student achievement rather than student growth (Rachmatullah et al., 2019; Unfried et al., 2014). This recent validation work on the T-STEM has established it as a theoretically sound and stable instrument (Rachmatullah et al., 2019). Therefore, the T-STEM CT is modeled after the T-STEM and was designed to be used as an additional subscale or as a stand-alone instrument to measure teacher efficacy for teaching CT.

Purpose

The purpose of this study is to develop, validate, and establish reliability on an instrument, the T-STEM CT, to measure in-service teacher self-efficacy in regard to teaching students CT skills and practices. The instrument is intended for use with teachers of all content areas in grades K-12. The following two central research questions guide this investigation:

1) Does the T-STEM CT instrument demonstrate evidence of reliability and validity?
2) What is the internal structure of the T-STEM CT?

Methodology

The methodological approach to develop and establish a valid and reliable instrument is described in the sections below. The instrument development process was guided by the *Standards for Educational and Psychological Testing* established by the American Educational Research Association, the American Psychological Association, and the National Council on Measurement in Education (AERA et al., 2014). First, the item development process is described, then the sample data collection efforts, and finally, the procedures applied to ascertain validity and reliability on the instrument.

Item Development

Items for the T-STEM CT were constructed through the modification of the teacher efficacy and outcome expectancy components of the larger T-STEM instrument (Rachmatalluh et al., 2019). Items were, therefore, rephrased to reflect in-service teacher beliefs about teaching CT. To help establish face validity, once initially modified, the items were reviewed by a team of CS education experts (Hardesty & Bearden, 2004). These experts were four research scientists who had been engaged in large-scale efforts working with in-service teachers to integrate CT in the classroom over the past few years. The wording of a few items was slightly modified as a result of this review to make them more comprehensible to the target population.

Once these items were refined, the researcher conducted cognitive interviews with respondents from the target population (Gehlbach & Brinkworth, 2011). Thus, six current K-12 teachers were interviewed to assess their understanding of the survey items and ensure that the items were interpretable (Karabenick et al., 2007). One item was slightly rephrased as a result of these teacher interviews. Tables 2 and 3 show a comparison of the original T-STEM technology subscale and the final T-STEM CT items for both the self-efficacy and outcome expectancy constructs, respectively. Mirroring the original T-STEM teaching self-efficacy subscales, the finalized version contained 20 items to assess teachers' self-efficacy beliefs for teaching CT along two dimensions: personal teaching efficacy beliefs (11 items) and teaching outcome expectancy beliefs (9 items). Respondents rated their agreement to each of the items on a five-point Likert scale: strongly disagree (1), disagree (2), neither agree nor disagree (3), agree (4), and strongly agree (5). See Appendix A for the full finalized instrument.

Table 3.2

Comparison of Original T-STEM and T-STEM CT Self-efficacy Items

	T-STEM technology subscale items	Final T-STEM CT items
1	I am continually improving my technology teaching practice.	I am continually improving my computational thinking teaching practice.
2	I know the steps necessary to teach technology effectively.	I know the steps necessary to teach computational thinking effectively.
3	I am confident that I can explain to students why technology experiments work.	I am confident that I can explain to students how computational thinking works.
4	I am confident that I can teach technology effectively.	I am confident that I can teach computational thinking effectively.
5	I wonder if I have the necessary skills to teach technology.	I wonder if I have the necessary skills to teach computational thinking.
6	I understand technology concepts well enough to be effective in teaching technology.	I understand computational thinking concepts well enough to be effective in teaching computational thinking.
7	Given a choice, I would invite a colleague to evaluate my technology teaching.	Given a choice, I would invite a colleague to evaluate me teaching computational thinking.
8	I am confident that I can answer students' technology questions.	I am confident that I can answer students' questions about computational thinking.
9	When a student has difficulty understanding a technology concept, I am confident that I know how to help the student understand it better.	When a student has difficulty understanding a computational thinking concept, I am confident that I know how to help the student understand it better.
10	When teaching technology, I am confident enough to welcome student questions.	When teaching computational thinking, I am confident enough to welcome student questions.
11	I know what to do to increase student interest in integrated technology.	I know what to do to increase student interest in computational thinking.

Table 3.3

Comparison of Original T-STEM and T-STEM CT Outcome Expectancy Items

	T-STEM technology subscale items	Final T-STEM CT items
1	When a student does better than usual in technology, it is often because the teacher exerted a little extra effort.	When a student does better than usual in computational thinking, it is often because the teacher exerted a little extra effort.
2	The inadequacy of a student's technology background can be overcome by good teaching.	The inadequacy of a student's background in computational thinking can be overcome by good teaching.
3	When a student's learning in technology is greater than expected, it is most often due to their teacher having found a more effective teaching approach.	When a student's learning in computational thinking is greater than expected, it is most often due to their teacher having found a more effective teaching approach.
4	The teacher is generally responsible for students' learning in technology.	The teacher is generally responsible for students' learning in computational thinking.
5	If students' learning in technology is less than expected, it is most likely due to ineffective technology teaching.	If students' learning in computational thinking is less than expected, it is most likely due to ineffective computational thinking teaching.
6	Students' learning in technology is directly related to their teacher's effectiveness in technology teaching.	Students' learning in computational thinking is directly related to their teacher's effectiveness in teaching computational thinking.
7	When a low achieving child progresses more than expected in technology, it is usually due to extra attention given by the teacher.	When a low achieving child progresses more than expected in computational thinking, it is usually due to extra attention given by the teacher.
8	If parents comment that their child is showing more interest in technology at school, it is probably due to the performance of the child's teacher.	If parents comment that their child is showing more interest in computational thinking at school, it is probably due to the performance of the child's teacher.
9	Minimal student learning in technology can generally be attributed to their teachers.	Minimal student learning in computational thinking can generally be attributed to their teachers.

Due to the ambiguous and evolving state of the term CT (Selby & Woolard, 2013), the participants were asked to apply the following definition of CT as they responded to each item:

> *A problem-solving process that applies key ideas from computer science such as algorithms, abstraction, pattern recognition, and decomposition. Computational thinking may involve programming and computers but does not have to. It is a human thought process that utilizes computational tools and concepts to solve problems.*

Survey Data Collection

The T-STEM CT is intended to be an instrument that can be used across K-12 teaching contexts; therefore, data were collected from a sample of K-12 in-service educators. Teachers were recruited to participate in the study through various professional listservs and social media outlets. Although the survey did not ask the respondents to disclose their geographical locations, it is surmised that the majority of the them resided in North Carolina considering that many of the targeted listservs and social media sources were within the author's local professional networks.

Recruited teachers completed the survey online after providing their consent to participate in the study. In addition to the 20 items that measured self-efficacy, participants were asked to report basic demographic information on their gender, race, years of experience in education, their primary position at the school, and the category of the grade level that they primarily work with (e.g., K-5, 6-8, 9-12). There were initially 339 responses to the survey; however, twenty-one respondents had one or more missing values within their responses. List-wise deletion was employed to eliminate these observations prior to running the analyses so that modification indices could be computed. After this data cleaning process, the final sample consisted of 318 observations that were used for the analyses described below. See Table 4 for demographic information collected from these participants.

Table 3.4

Participant Demographics of the Final Sample

	%
Gender:	
Female	81.4
Male	18.2
Not Disclosed	0.3
Race/Ethnicity:	
American Indian	0.3
Asian	2.5
Black/African American	12.6
White/Caucasian	79.2
Hispanic/Latino	1.6
Multiracial	1.9
Other	1.6
Teaching Experience:	
0-3	11.6
4-9	21.1
10-14	22.6
15-19	18.6
20-29	20.4
30+	5.7
Position:	
Classroom Teacher	95.0
Instructional Support	3.2
Administrator	1.6
Other	0.3
Grade Level:	
K-5	21.7
6-8	47.8
9-12	24.8
Other	3.5

Data Analysis

According to Messick (1995), validity refers to how well empirical and theoretical evidence supports an instrument's intended use and measurement interpretation. AERA et al. (2014) argue that validity is the most important factor in test and survey development. Therefore, the following sections describe how confirmatory factor analysis (CFA) was used to establish construct validity (DeVellis, 2016). Because the survey was based on an already validated instrument founded on well-established theoretical constructs (Bandura, 1997), CFA was chosen as the most appropriate analysis given these *a priori* hypotheses regarding the latent factors and measured variables (Thompson, 2005). Descriptive statistical analyses were computed using IBM SPSS software, version 26, and the CFA was performed using AMOS software, version 26 (Arbuckle, 2019). The reverse worded item was recoded to facilitate the interpretation of the results prior to the analyses. Because CFA presumes multivariate normality, skewness and kurtosis indices for the measured variables in the data set were computed. All items were normally distributed with values that did not exceed |1.5| in magnitude (George & Mallery, 2016; Petscher et al., 2013).

A two-factor model was specified to reflect Bandura's (1997) self-efficacy theory as consisting of two distinct sub-constructs: personal self-efficacy and outcome expectancy. Eleven of the items were modeled as indicators of one's personal self-efficacy for teaching CT factor, while the other nine items indicated one's outcome expectancy for teaching CT. In alignment with the scale's theoretical underpinnings (Bandura, 1997), the latent factors were allowed to correlate to reflect the intimate and reciprocal relationship of the two sub-constructs. Ultimately, two models were tested, and following recommendations from Kline (2016), the overall fit between the proposed models and the data were assessed using the following fit indices: chi-square goodness-of-fit index, *chi-square/df* ratio, comparative fit index (CFI), Root Mean Square Error of Approximation (RMSEA), and the Standardized Root Mean Square Residual (SRMR). Given that the data were determined to follow a normal distribution, the Maximum Likelihood estimator (Brown, 2015) was used to calculate the parameters of the model. As recommended in the literature, the following cut-off criteria for the fit indices was used to guide the analyses: $\chi^2 <$

2; χ^2/df = < 2; RMSEA ≤ .05; CFI > .95; SRMR ≤ .05 (Hu and Bentler, 1999; Schermelleh-Engel et al., 2003).

Results

Fit statistics for the initial model indicated an adequate fit, χ^2 (169) = 346.395, p < .000; χ^2/df = 2.05; RMSEA = .058, 90% CI [.049, .066], pclose = .075; CFI = .943; and SRMR = .060. Although this specified model demonstrated good to adequate fit, following a practice widely followed by the research community, the modification indices were inspected to consider potential enhancements to the model (Brown, 2003, 2015; Marsh, 1996). Examination of the modification indices showed strong evidence of correlated residuals amongst two different item pairs within the outcome expectancy scale: items CTTOE01 and CTTOE02 (modification index = 14.06, standardized expected parameter change = .09) and items CTTOE07 and CTTOE08 (modification index = 12.83, standardized expected parameter change = .11). Upon inspection of the content and the context of these items within the survey, there seemed to be substantial justification for rerunning the model with these correlated residuals.

The refined model had better fit-indices and several of the fit statistics indicated good model fit overall, χ^2 (167) = 317.661, p < .000; χ^2/df = 1.902; RMSEA = .053, 90% CI [.044, .062], pclose = .261; CFI = .952; and SRMR = .0584. For example, CFI was above the .95 cutoff value suggested by Hu and Bentler (1999), SRMR and RMSEA values moved closer to the .05 cutoff value recommended by Schermelleh-Engel et al. (2003) that indicate a good fit. Table 5 shows that four of the goodness-of-fit indices: χ^2, χ^2/df, RMSEA, and SRMR values were appropriately lower in the second model providing sufficient evidence for a good fit between the data and this model and demonstrating good overall factorial validity. There was a modestly significant correlation between the latent variables (*r* = .12, *p* < .032). The final model is shown visually in Figure 1.

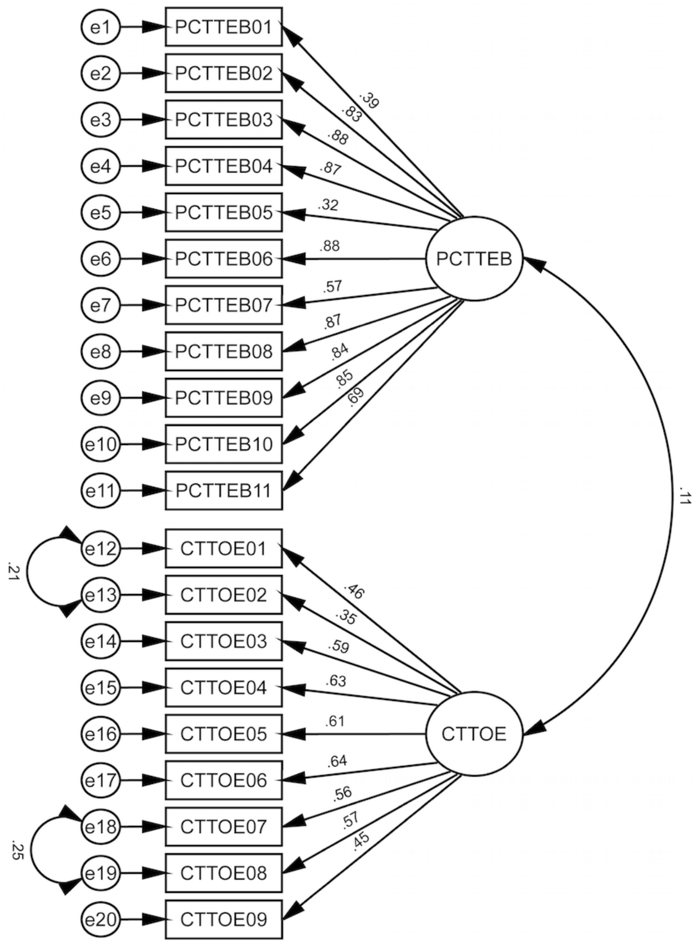
Table 3.5

Comparison of CFA Results by Model

Indicator	χ^2	*df*	χ^2/df	CFI	SRMR	RMSEA	90% CI
Model 1	346.395	169	2.05	.943	.06	.058	.049, .066
Final Model	317.661	167	1.90	.952	.058	.053	.044, .062

Figure 3.1

Final Model and Factor Structure of T-STEM CT Scale with Standardized Regression Weights



Psychometrics Properties of the Scale

Generally speaking, reliability refers to the consistency of an instrument, and various statistical procedures can be applied to determine reliability for different purposes (Huck, 2000). Benson and Clark (1982) assert that the type of reliability measures used depend upon the intended purposes for the instrument. Considering that this instrument is based upon Bandura's (1977) theory of self-efficacy beliefs which is comprised of both personal self-efficacy and outcome expectancy, internal consistency reliability (Cronbach's alpha) is a useful metric to determine how well the items in each of these subsets measured these two distinct constructs (DeVellis, 2016). After the best model fit was determined, internal consistency analyses were performed using SPSS (version 26.0.0) on the two factors by computing Cronbach's alpha. Overall, the total scale was .868; with .921 for the PSE subscale and .792 for the OE sub-scale. These coefficients show good internal consistency for each of the subscales and the total scale (George & Mallery, 2016). See Table 3.6 for correlation and reliability information for each scale and individual subscale items.

Table 3.6

Reliability Statistics for T-STEM CT items

Item	Corrected item-total correlation	Cronbach's α if deleted	Cronbach's α
Total scale			.868
Self-efficacy items			.921
PCTTEB01	.378	.928	
PCTTEB02	.806	.908	
PCTTEB03	.832	.907	
PCTTEB04	.839	.907	
PCTTEB05	.285	.933	
PCTTEB06	.838	.906	
PCTTEB07	.541	.921	
PCTTEB08	.834	.907	
PCTTEB09	.789	.909	
PCTTEB10	.832	.907	
PCTTEB11	.664	.915	
Outcome Expectancy items			.792
CTTOE01	.426	.779	
CTTOE02	.343	.789	
CTTOE03	.522	.766	
CTTOE04	.533	.765	
CTTOE05	.517	.767	
CTTOE06	.553	.762	
CTTOE07	.517	.767	
CTTOE08	.538	.765	
CTTOE09	.382	.786	

Discussion

The initial model tested was based on the hypothesis that teachers' self-efficacy for teaching CT would consist of two latent factors. This hypothesis was based on prior theory and empirical findings regarding teacher self-efficacy beliefs aligned with Bandura's conceptualization (e.g., Bandura, 1977, 1997; Riggs & Enochs, 1990). This study helped to confirm that teacher self-efficacy for certain content domains like CT consists of two separate latent factors, the confidence in their ability to teach it, and the belief that the effort they exert teaching will positively impact student outcomes. Results from this study support the initial hypothesis and is consistent with other well-established instruments designed around Bandura's description of self-efficacy and outcome expectancy as two distinct factors such as the STEBI-A (Riggs & Enochs, 1990), the STEBI-B (Enochs & Riggs, 1990), the MTEBI (Enochs et al., 2000), and the T-STEM (Rachmatalluh et al., 2019). Furthermore, the scale demonstrated good validity and psychometric properties, indicating its potential value as a useful instrument to evaluate the two components of in-service teachers' self-efficacy for teaching CT.

Standards for validity and fairness were adhered to throughout the survey development and validation process, as recommended by AERA et al. (2014). First, the guidance of experts in the field of computing education to develop and review items were solicited. Then, cognitive interviews were implemented with the target population to garner additional feedback for item revisions. It was also ensured that the participant sample for this study included subgroups representative of the potential diversity of our target population (e.g., grade level, professional teaching experience, race, and gender). Validity and reliability evidence on the internal structure of the instrument were provided; however, instrument development is an ongoing process and necessitates various types and multiple sources of validity evidence (AERA et al., 2014; Messick, 1995). As such, it was beyond the scope of this study to address all of the recommended standards and several of these limitations are outlined accordingly in the next section.

Whereas the first model that was tested demonstrated an adequate fit, the model indicated a better fit when the unique variances of specific item pairs within the outcome expectancy subscale were allowed to correlate. These items were identified by examining the modification indices generated by the first model to determine whether or not any there was substantial justification to let any of the error terms between indicators correlate freely (Brown, 2003, 2015).

Brown (2003) argues that covariance among indicators might be due to an extraneous common cause such as content overlap, item wording, or other response set biases rather than random error and if theoretically or methodologically warranted, the model should then be adjusted accordingly. Therefore, the content of the two item pairs of interest and their placement within the survey were carefully inspected for potential methodological or trait effects that were not accounted for by the latent factor (Brown, 2003, 2015; Marsh 1996). Upon this inspection potential contextual effects related to the similarity of each item pairs' content and their proximity to one another within the survey were identified (Tourangeau et al., 2000). As such, it was determined that these items' error terms should be correlated appropriately within the model due to systematic response bias which engendered common sources of nonrandom deviation from the responses' true values (Villar, 2008).

For items CTTOE01 and CTTOE02, ("When a student does better than usual in computational thinking, it is often because the teacher exerted a little extra effort" and "The inadequacy of a student's computational thinking background can be overcome by good teaching"), both of these items appeared in the survey adjacent to one another and both reference an individual student that is presumed to be academically behind their peers. Likewise, items CTTOE07 and CTTOE08, ("When a low achieving child progresses more than expected in computational thinking, it is usually due to extra attention given by the teacher" and "If parents comment that their child is showing more interest in computational thinking at school, it is probably due to the performance of the child's teacher"), are not only asked in succession to one another but they also have similar item phrasings in that a child demonstrating "more" of something that is "due to" the teacher. Thus, it is likely wording of the first item had a priming effect on participants' responses to the second item (Tourangeau et al., 2000).

Conclusion

Because instrument development is an ongoing process and necessitates various types and multiple sources of validity evidence (AERA et al., 2014; Messick, 1995), further research is needed to continue to build a validation basis for this instrument. New data collection efforts that extend the survey to different contexts, settings, and sample populations can address measurement invariance across key demographics. Future administrations of the survey should also pursue further validity evidence such as criterion-related and convergent validity.

Finally, because the items on the T-STEM CT require respondents to self-report their ability to teach CT in a broad sense, results from the measure will be a reflection of each individual teacher's definition of CT. Thus, findings from the measure should be interpreted accordingly.

Prior research has established the importance of examining teachers' beliefs, such as self-efficacy, for gaining a better understanding of their predisposition to integrate technology (Ertmer & Ottenbreit-Leftwich, 2010; Ertmer et al., 2012). Computational thinking is a critical 21st Century skill that teachers must be able to integrate into their classrooms to adequately prepare students for a future that increasingly relies on technology. Review of the literature to date indicates there is still much to be learned about teacher efficacy beliefs with CT instructional practices, and a widely accepted, validated instrument that would provide a reliable metric could help to forward this area of research.

The T-STEM CT offers a concise, yet a seemingly valid measure of in-service teachers' self-efficacy for CT that is firmly grounded in Bandura's theoretical framework of the construct. The scale's brevity makes it potentially useful for a wide variety of applications where it is necessary to measure teacher self-efficacy for CT. The creation of a validated instrument to evaluate teachers’ self-efficacy for teaching CT is an important contribution to future scholarly pursuits that allow researchers to design more robust studies. In particular, the ability to consistently assess teachers’ self-efficacy levels with CT practices can help to inform the design of professional development initiatives and curricular materials for teacher use, synthesize and draw conclusions from results across various studies, as well as enable individuals to assess the effectiveness of such interventions appropriately.

Chapter Four: An Investigation of School Leadership Practices for School-wide Professional Learning to Integrate Computing

Computational thinking (CT) and computer science (CS) have become recognized as critical 21st Century skills needed for individuals to fully participate in a global society dependent upon technology (Grover & Pea, 2013; Wing 2006). Many argue that these skills are as relevant as the 3 R's, and therefore students should learn them as a part of their regular K-12 schooling (e.g., Barr & Stephenson, 2011; NRC, 2010; Sanford & Naidu, 2016; Wing, 2006, 2008). Unfortunately, opportunities to learn these essential skills and practices are often the exception rather than the norm (Google and Gallup, 2016; Grover & Pea, 2013).

Introductory CS classes are still most commonly offered in high school as specialized electives or advanced placement courses (Code.org Advocacy Group & CSTA, 2018; Mannila et al., 2014; Yadav et al., 2016b). Although younger students are beginning to have greater access to informal CT and CS learning through afterschool and summer enrichment programs, like elective classes, there are often self-selection and exclusion biases that preclude students from participating in these programs (Buffum et al., 2016). Furthermore, large segments of the U.S. population, such as women, African Americans, and Hispanic/Latinx, have been historically marginalized from computing and other STEM disciplines (Code.org Advocacy Group & CSTA, 2018; Google & Gallup, 2016). Providing opportunities for all students to learn and develop interests in these practices with early exposure through core classroom experiences is one strategy to broaden participation in these fields (Barr & Stephenson, 2011; Buitrago Florez et al., 2017; Grover & Pea, 2013; Mishra et al., 2013; Yadav et al., 2017). Integrating CT and CS into content domains that are part of the compulsory curriculum, (e.g., English Language Arts (ELA), science, math, social studies) enables all students to participate in these practices. Additionally, they learn how CT and computationally-intensive tools are used across disciplines (Mishra et al., 2013; NRC, 2011; Yadav et al., 2014). Therefore, widespread integration of CT and CS across the curriculum is imperative so that all students have exposure to these important skills and become prepared for a future that is increasingly dependent upon them (Sanford & Naidu, 2016).

Unfortunately, the majority of K-12 non-CS teachers lack the necessary training and skillsets to integrate these practices within their disciplinary areas (Garvin et al., 2019; Kale et al., 2018a; Sands et al., 2018). Thus, finding ways to support K-12 classroom teachers to integrate CT and CS within their content areas is critical (Barr et al., 2011; NRC, 2011).

Current CT and CS training models for in-service teachers are typically off-campus, multi-day workshops where teachers learn these skills decontextualized from their school and classroom contexts, often isolated from their colleagues (Lockwood & Mooney, 2018). Teachers are then tasked with going back to their schools to implement new knowledge and skills with little to no follow-up support. This is problematic, as prior research has noted numerous challenges that confront teachers as they experiment with implementing CT/CS within their school contexts including lack of administrative support, little time to plan and refine new lessons, an absence of school-level technical and pedagogical expertise, and limited instructional time due to testing and curriculum mandates (Bower et al., 2017; Israel et al., 2015; Kale et al., 2018a; Lockwood & Mooney, 2018). Likewise, teachers indicate that they would benefit from resources such as peer advice, mentoring, and time to collaborate with colleagues to design CT/CS lessons (Bower et al., 2017; Garvin et al., 2019; Israel et al., 2015; Pollock et al., 2017). Therefore, if we expect integration to occur across K-12 schooling, we must devise strategies to support teachers as they learn and grow these skills within their schools.

School-wide CT initiatives offer a potential model that allows teachers to learn how to integrate CT within their schools and classrooms alongside their peers (Israel et al., 2015; Lockwood & Mooney, 2018). These models can offer much needed localized assistance such as “support groups that include peer learning and teaching buddies,” and “resources (e.g., computers, time) for teachers to develop teaching materials” (Bower et al., 2017, p. 66). However, there is a scarcity of literature that has examined the design and implementation of school-wide CT or CS initiatives (Israel et al., 2015). Questions remain about how such models should be led and executed, including the necessary resources and capital to sustain them. To fill this research gap, this study investigates how a group of educators at one middle school devised and led a school-wide professional learning initiative designed to support computing integration across the curricula using block-based programming. The essential research question was: “How do a team of educators at one middle school collectively lead a professional learning initiative on computing integration within their school?” Using a distributed leadership framework, this question was parsed into the following two sub-questions:

- How are leadership practices distributed amongst the team and within the larger school context?
- What aspects of the situation (context) enable or constrain the leadership practices?

Distributed Leadership for Technology Integration

Recent research on school-wide technology initiatives underscores the importance of a distributed leadership approach where individuals beyond the principal take active roles leading and directing such efforts (e.g., Christensen et al., 2018; Shear et al., 2014; Sun & Gao, 2019; Toh, 2016). Distributed leadership as a conceptual framework rests on the following assumptions: effective school leadership requires multiple leaders; leadership practice occurs through the interactions of leaders, followers, and the context of their situation (see Figure 4.1); and, situation mediates leadership practice as both are defined and redefined through the process (Gronn, 2000; Spillane, 2006). With a distributed perspective on leadership, the unit of interest becomes the leadership activity, including the various practices and tasks that leaders engage in and how that work impacts the activity as a whole (Spillane et al., 2004). Also, central to a distributed leadership framework is elucidating how various aspects of the situation like tools and routines facilitate, constrain, and give shape to practice (Gronn, 2002; Spillane, 2006).

Figure 4.1

Distributed Leadership as Represented by Spillane (2006).

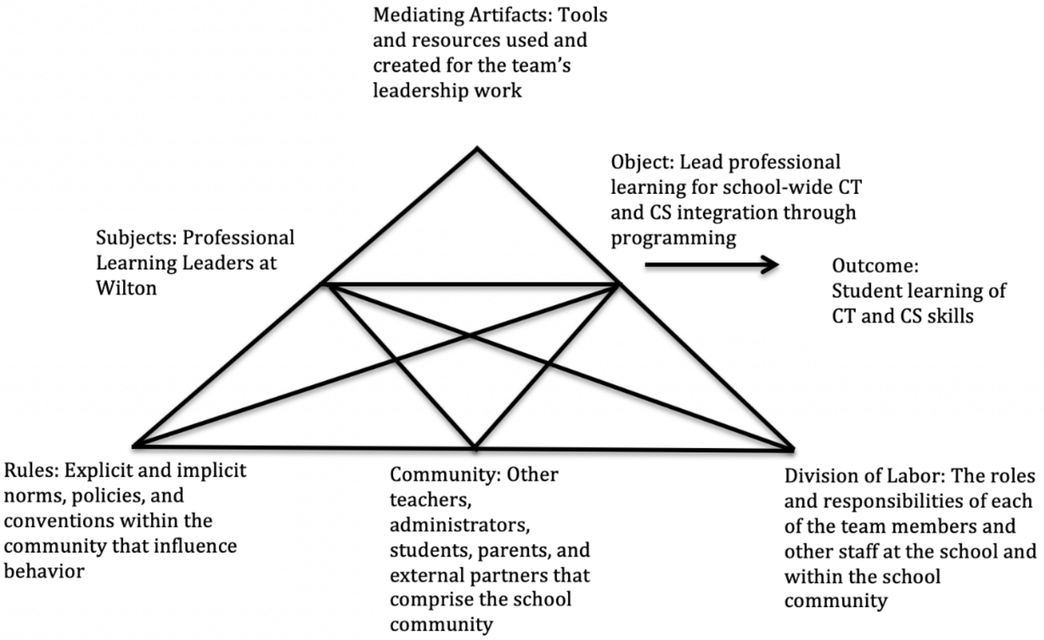
Although distributed leadership continues to be a popular theoretical framework to study how educators lead innovative reforms in schools, some have begun to note its conceptual shortcomings needed for in-depth analysis (e.g., Hirsch & Segolsson, 2019; Ho et al., 2016; Vennebo, 2017). These scholars argue that applying a theoretical lens based solely on distributed leadership fails to capture the more nuanced roles of individuals as they negotiate and execute their leadership work within complex socio-cultural contexts such as schools (Hauge & Norenes, 2015; Hirsch & Segolsson, 2019; Ho et al., 2016; Tay & Lim, 2016). Distributed leadership has its theoretical foundations in cultural-historical activity theory (CHAT) (Gronn, 2002; Spillane et al., 2004); thus, there is merit in analyzing studies of distributed leadership using CHAT.

Activity Theory as an Analytical Tool

CHAT offers researchers a holistic approach for understanding human activity by examining how individuals interact with their social entities to achieve object-oriented goals (Barab et al., 2004; Kaptelinin & Nardi, 2006; Kuutti, 1999). Vygotsky (1978) proposed that human activity occurs within a triadic system that includes the individual subject, the object at which an activity is directed, and mediating artifacts. Engeström (1987/2015) expanded Vygotsky's original activity triangle (e.g., subject, object, tool), to underscore the collective and contextual nature of human activity by adding the components community, division of labor, and rules. Community consists of all individuals and subjects involved in the activity who share the same object. Division of labor constitutes how that community divides tasks amongst its subjects, both horizontally and vertically, as influences of power come to play within the activity setting (Engeström & Sannino, 2010). Finally, rules reference both the explicit and implicit norms that prescribe actions within the activity system (Engeström & Sannino, 2010). See Figure 4.2 for a graphical representation of the activity system comprising the leadership work. According to Engeström (1987/2015), contradictions that arise between components of an activity system often serve as catalysts for its expansion as resolutions to tensions evolve and transform the activity for all participants.

Figure 4.2

Representation of the Leadership Work as an Activity System



Hirsch and Segolsson (2019) were also able to provide a more fine-grained interpretation of how a principal and eight lead teachers distributed organization, knowledge, and skills to incorporate a model that facilitated school-wide change by applying CHAT as an analytical tool. Ho and Ng (2016) found CHAT particularly useful for illuminating how leadership work in schools was enabled and constrained by their socio-cultural and historical contexts. They noted that contradictions within the activity system and with competing activity systems were often sources of innovations that evolved the activity as tools and rules were manipulated to resolve tensions.

Utilizing CHAT as an analytical framework has methodological implications for researchers. First, an object-oriented activity setting becomes the unit of analysis, as human action is seen as part of a larger artifact-mediated collective endeavor shaped by the socio-cultural context where it occurs (Engeström, 1987/2015; Ramanair, 2016; Yamagata-Lynch, 2003). In this study, the leadership work of the team at Wilton Middle School (a pseudonym) is viewed as the activity system and unit of analysis. Because CHAT considers subjects as independent agents, both their individual and collective actions are analyzed as mediated by the social and material resources within the school community. In sum, CHAT is utilized to identify, describe, and analyze each component within the activity system (e.g., subject, object, tools) and their dynamic inter-relationships to understand how the team pursued goals related to the school computing initiative under a variety of sociocultural conditions. Finally, using CHAT as an analytical tool requires that many participant perspectives within the activity system are accounted for by the researcher (Rasmussen & Ludvigsen, 2009).

Methods

Instrumental case studies can be powerful opportunities to study a particular phenomenon of interest (Stake, 1995). In this study, the leadership work to be carried out by a school-level team was an opportunity to understand how a distributed leadership model and its associated leadership practices could drive a school-wide professional learning initiative for computing integration. Stake (1995) describes a case as a bounded, integrated system; thus, the team's leadership work served as the appropriate unit of analysis. Furthermore, naturalistic inquiry grounded in a case study approach enabled an in-depth and holistic understanding of the various leadership actions of the participants as they interacted within the school community and its unique environment.

Research Context

Wilton (a pseudonym) is considered a mid-sized middle school with 830 students located in the southeastern region of the United States (see Table 4.1 for student demographic information and Figure 4.3 for the school organizational structure). Wilton became a designated

STEM-focused magnet school three years ago and began working with a nearby university to help operationalize its theme shortly after its designation. Over those three years, university staff members provided professional development on CT concepts to all teachers, while science education and CS education researchers began working with science teachers to implement computational modeling lessons in their classrooms. As a result, teachers integrated CT terminology (e.g., pattern recognition, abstraction, decomposition, and algorithms) within their lessons. However, CT was still largely being taught in the absence of technology.

Building upon the foundational partnership, Wilton and the university established a formal research-practice partnership (RPP) that focused on broadening participation in CT and CS learning opportunities throughout the school last school year. As such, the RPP team (university staff and members of school administration) sought to encourage teachers to adopt technology and computer science practices to integrate CT more authentically within the school. To meet the larger goal of the RPP, the RPP team decided on a strategic objective to establish a corps of leaders within the school. This group would lead a school-wide professional learning initiative to support coding integration in all disciplinary classes and subjects (e.g., electives, science, math, social studies, ELA). The RPP team chose the block-based coding platform Snap! as the primary vehicle for this integration due to its management flexibility and user-friendly interface (Lytle et al., 2019).

Participants

The RPP team extended an open invitation to all school staff members to be a part of the professional learning leadership team. The RPP also offered stipend incentives for each component that would comprise this leadership work. For example, they would be compensated for each external professional development session that they attended and the sessions they planned and led within the school. As a result of this recruitment, eleven staff members volunteered to be a part of this special leadership team. As Table 4.2 shows, they represented various formal roles throughout the school. These participants were required to commit to the following: 1) attend a three-day summer professional development workshop on CT integration with Snap! coding, 2) implement coding units with students during the school year, and 3) provide structured and informal professional development to the teaching staff throughout the school year. Although these eleven participants were the main subjects of the research study, other staff, including teachers and principals, were interviewed and surveyed to elicit their perceptions of the team's leadership work.

The summer professional development was designed exclusively for this leadership team by the university partners. It consisted of a basic introduction to Snap! programming and CT; hands-on programming activities within the Snap! environment; the intersection of programming, CT, and disciplinary learning; and time for teachers to develop an integrated computing lesson that used Snap! programming. The team was also provided time to discuss and plan strategies for leading the school-wide initiative in the fall.

Figure 4.3

Wilton Middle School Organizational Chart

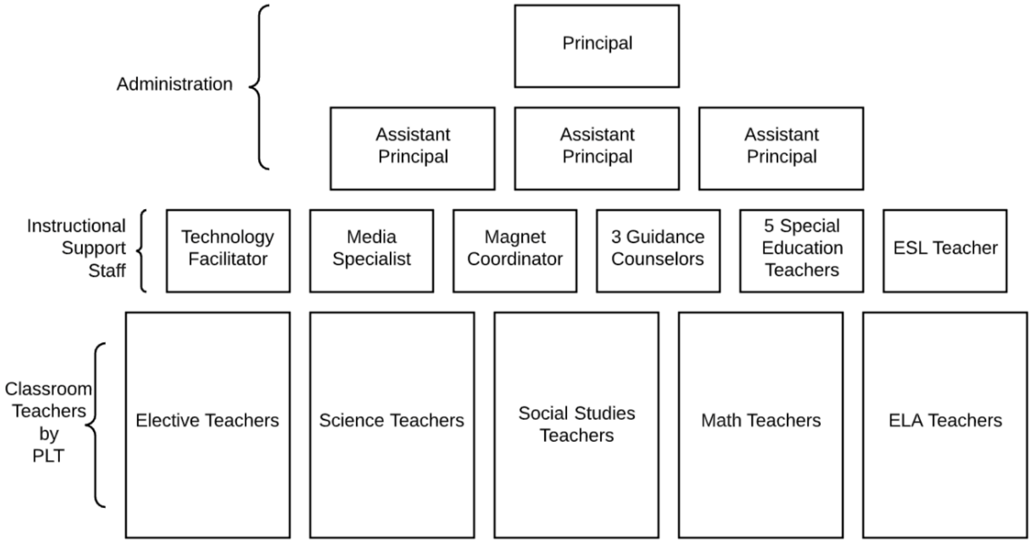


Table 4.1

School Demographic Information

Race/Ethnicity	%	Other Demographic Information	%
White	43.8	Free or reduced-price lunch	39.6
Hispanic	24.1	Special Education	19.2
Black	19.9	Limited English Proficiency	06.2
Two or more races	06.3	Academically/Intellectually Gifted	16.5
Asian	05.7	Identify Male	55.5
Native American/Pacific Islander	00.2	Identify Female	44.5

Data Source: National Center for Educational Statistics

Table 4.2

Professional Learning Leader Participants

Name (Pseudonym)	School-level Role
Renee	Assistant Principal
Leslie	School Magnet Coordinator
Jeanine	Instructional Technology Facilitator
Audrey	Media Specialist
Cass	Math Teacher
Taryn	Science Teacher
Cindy	Science Teacher
Maria	Science Teacher
Samara	Science Teacher
Suzanne	Social Studies Teacher
Ashli	Special Education Teacher

Data Collection

Interviews

Formal interviews were conducted with each of the team leaders at various time points throughout their involvement in the study: before and after the summer professional development, during the first and second quarters of the school year, and a final interview towards the end of the school year. These interviews followed semi-structured protocols to elicit the leaders' perceptions of their roles, actions, effects of those actions, as well as enablers and barriers to their efforts. Individual interviews and focus groups were also periodically conducted with other teachers and administrators throughout the study to garner their perspectives on the leadership activity. See the Appendices for all interview protocols. All interviews were audio-recorded and transcribed by a professional transcription service.

Surveys

To appraise and inform the design of their professional learning sessions, the leaders collected formative data after each session. These brief surveys, in the form of exit tickets, often asked staff to report on what they liked and disliked about the session. The researcher used these surveys as an additional data source for gaining staff perspectives on the effectiveness of the professional learning. Appendix E contains all exit ticket survey questions.

Video Recordings

The summer professional development, formal professional learning sessions with staff, and team's leadership meetings during the school year were all video-recorded for observation and analysis.

Artifacts

A variety of digital and physical artifacts produced by participants throughout the initiative were also collected for analysis. These included staff Tweets, meeting notes and agendas, websites and web resources, lessons and lesson plans, e-mails, and presentations used for professional learning.

Data Analysis

All data sources were imported into Atlas.ti (version 8) and coded using an *a priori* coding scheme derived from the various elements of CHAT (e.g., subject, follower, rules, division of labor, community, object, constraint, enabler), where each meaning unit was assigned one or more codes. Once coding of each data source was complete, to aid in the data reduction process, Atlas.ti was used to group quotations of common codes by data source type (e.g., interviews with leaders, video-recorded leadership meetings, etc.) to note emerging themes related to each component of the activity system. This condensed data was then integrated and analyzed for holistic patterns and themes across all data sources in relation to the research questions.

Credibility

A variety of strategies were employed throughout the data collection and analysis phases to enhance the credibility of the data and its findings. First, there was a triangulation of multiple data sources to capture various participant perspectives and ensure that findings from each source were corroboratory (Patton, 2002). Member checks were also periodically conducted with participants as early themes emerged throughout the research process (Merriam, 2015). Finally, multiple observations and site visits were conducted throughout the school year to collect rich and reliable sources of data (Creswell, 2013).

Findings

Several themes emerged regarding the team's distribution of leadership practices, including how they individually and collectively engaged in leadership tasks, utilized elements of the activity system to shape and further the object, and how they capitalized on enabling factors both within their leadership model and the school ecosystem to resolve constraints.

Subjects and Division of Labor

> "I think we have a very diverse group of program leaders. They span all of the subjects. I think that was helpful to get teachers to buy in," (ELA teacher interview).

The team's diverse composition facilitated the distribution of their leadership practices and coordination of critical elements within the activity system towards the object. Collectively, they represented a multitude of perspectives across the school community, which enabled them to meet a broader range of staff and student needs.

Classroom Teachers

Teachers at Wilton regularly collaborated within subject-area professional learning teams (PLTs), meeting at least once a week to plan lessons, often within pairs by grade level (termed PLT partners). The classroom-based leaders capitalized on the trusted relationships that they had established with these same-subject peers to acquaint them with curricular-area coding. Two of the leaders were able to leverage both established trust and routine co-planning practices to encourage their PLT partners to co-implement lessons that they had developed during the summer professional development prior to any training. Suzanne explained how this materialized for her:

> "I first worked just with my PLT partner because I had already created the activity. And so, I mainly worked with her at first, just talking through the activity, how it was going to work in the classroom, and then actually implementing it. I mean I kind of just told her this is what we're doing, and we do everything the same."

Her PLT partner elaborated how peer trust facilitated her willingness to try something new, "I really like [Suzanne] and respected that this could be something that would work."

The classroom-based professional learning leaders were also able to offer their PLTs disciplinary expertise, with specific guidance of how coding could forward content-area learning. "I think overall coming from other teachers; we can kind of make it a little bit more relatable. I can show you how to make it work for your content," (Taryn interview). Additionally, as the teachers honed the pedagogical skills that they had learned during the summer professional development, they shared instructional strategies such as pair programming, debugging, Parson's problems, and unplugged activities. Peer-teaching became a powerful approach for learning these skills, "I think having teachers teach their peers is helpful. It's not having an outsider come in that has no connection to the teachers or the curriculum, that's not as impactful as having one of their own," (Principal interview).

The classroom-based leaders, perceived as non-CS experts who integrate coding into their curricula, also became role models for their peers. "I think they all know me as a real person. They know [Taryn] is not a computer scientist, like none of us were computer geniuses," (Maria interview).

Instructional Support Staff

While having classroom teachers serve as professional learning leaders enhanced the relevancy of the initiative for the teaching staff, the other members of the team had unique expertise and access to resources that extended the team's capabilities. Most notably these individuals a) created resources, b) channeled support, c) facilitated communication, d) structured and organized activities, and e) supported the leadership work of the classroom professional learning leaders.

One of the crucial commodities that the instructional support professional learning leaders contributed was time to work on organizational tasks and creating resources for the initiative, a luxury not afforded to the classroom teachers because of teaching obligations. Jeanine (Technology Facilitator) explains how she viewed her distinct contributions to the team, as a non-disciplinary resource person:

> "So, a generalist like myself, I'm working here because everybody needs to know how to import a background [into Snap!]. So, what tool do you have to help you do that? I don't want you not to have a background because it took you 50 hours to find one the right size. And [Audrey] does that too, she takes a grander scale, and here's a little video to show you how to do this and that. So, I think you need support people who are willing to create that…resources."

Audrey (Media Specialist) also often took the lead designing each month's professional learning session, preparing slides and agendas for team feedback. The flexibility of their schedules allowed them to offer the classroom-based leaders opportunities to extend their leadership practices by covering classes so they could lead professional learning sessions outside of their PLTs or co-teach newly developed lessons in their peers' classrooms.

The instructional support leaders also leveraged relationships and trust from key stakeholders. Leslie (Magnet Coordinator) used her close collegial relationship with the principal to convince him to designate time in the school calendar for mandatory professional learning sessions. Audrey, Leslie, and Renee's positions at the school had them actively communicating and collaborating with community stakeholders to support school activities. Thus, they easily facilitated community support for the initiative, such as coordinating CS expertise from the university team and the PTA for snacks during the professional learning sessions.

As a school administrator, Renee's presence on the team helped garner both administrative and teacher buy-in for the initiative, conveying a message to the staff about its priority. "I'm glad Ms. [Renee] took the time to be a part so she could learn the concept and what we're doing. I think it would be beneficial if all the administration would be a part of it," (Teacher interview).

Renee hoped her willingness to learn new skills as an administrator and self-professed "technophobe" would position her as a role model for the rest of the staff,

> "So, I have to do this because it's something that I kind of am challenging myself and I don't want to be an administrator where I just say, 'you do this, you do that,' and I don't know how to do it."

Audrey used her responsibilities as the school webmaster to create a resource page with access to relevant links and materials to support teachers' efforts. She was also pivotal in securing the necessary technology for both the professional learning sessions and classroom implementations. Ultimately, Audrey became recognized by her peers as a critical point person for setting up infrastructure supports needed by all. “Audrey is amazing. She’s gotten us all the technology and helped with that. And she’s been great with getting the professional learning going, you know, making sure getting the scheduling is set up for that,” (Leslie interview).

Likewise, three of the team leaders (Leslie, Cass, and Samara) were also members of the school improvement team, which already had a subgroup that focused on technology integration. Because the goals of both of these teams aligned, they were able to integrate their efforts and advocate for the initiative as part of the school improvement process.

Collective Efforts

Although the diversified school-based roles and responsibilities of the professional learning leaders enabled each to provide individualized contributions towards the objectives of the initiative, ultimately, it was the collective coordination of their practices that made the endeavor more successful. The team worked together curating and pooling resources as they supported and encouraged each other’s efforts. Oftentimes, when one member was leading a professional learning session, other members in the room were observed helping and supporting the session leader and providing participants with individual assistance. These efforts helped to ensure that all of the staff’s questions and needs were adequately met during professional learning.

The team worked on many levels to present themselves as ‘a united front.’ At the beginning of the school year, when Cass was experiencing pushback from her math PLT, other team members stepped in to support her work with them.

> “We went through some of the pitfalls together. Some of those struggles as we were learning together and helped each other because I would maybe have a strength in something that somebody else wouldn’t or I was struggling in something and then

> [Suzanne] could jump in and be like, 'No, no, you go here.' And that was a huge thing. I mean, we all helped each other. And we really worked as a team, and that was awesome to see us do that across the content areas," (Cass final interview).

Leveraging Tools and Aligning Rules

Team leaders strategically utilized existing resources and norms within the school, as well as created new ones to forward the initiative. Some of the key tools and strategies that emerged are presented below.

Professional Learning Sessions to Meet Teacher's Evolving Needs

The team convinced school leadership to dedicate one monthly professional learning session during teachers' planning periods to learn more about coding and how it could be integrated into the curriculum. Planning periods at the school were already structured by subject area (e.g., math, ELA, electives), and the team leveraged this configuration to deliver more customized and intimate learning experiences with "small numbers" and help from "supportive collaborators" (Participant feedback from professional learning exit tickets).

The team collaboratively planned sessions that incrementally prepared the staff for the ultimate goal of developing and teaching their own integrated coding lesson. Instead of devising a protocol for professional learning at the outset, they collected and utilized participant feedback as a tool to design customized professional learning. For example, the first two sessions presented opportunities for the staff to become acclimated to the affordances of block-based coding by going through a series of generic programming activities. However, participants were asked how the session could be improved, responses such as "share its application in other areas," and "more related to content areas," indicated that many were failing to see a connection between coding and their curricular goals. Accordingly, the team redesigned their approach for the next session, where each PLT lead shared disciplinary-specific programs for teachers to explore and recognize its disciplinary value:

> "I think the more that we are getting it applicable to our own content it's making more sense. When I first started it was a little overwhelming and it didn't feel like you could apply it to everything," (ELA teacher).

The team once again reevaluated their plans when staff feedback, (e.g., "more time and practice", "slow down/have more directions", "let us create our own"), demonstrated that teachers were at different levels of comfort and readiness. The remaining sessions were then designed to afford teachers three options based on their individual professional learning needs: 1) learn more about coding basics through self-paced lessons (developed by the professional learning leaders) with individual support as requested; 2) engage in "buddy work" with a leader (one on one or in small PLT groups) to design an integrated lesson; 3) or work on other professional learning modules offered by the district.

A Leadership Team PLT

During the summer professional development, the team decided that it would be fruitful to meet and plan leadership work at designated times throughout the school year. They decided to utilize an already existing committee led by Audrey for this function, the School Technology Committee (STC), as its purpose focused on planning for technology use in the school.

> "So, the fact that we already had a committee in place and we only had a few members that were carrying over from the year before we were like, 'Let's just make everybody [in the leadership cohort] do this.' Because if I said, 'Everybody, let's come chat for a few minutes after school,' nobody would have come," (Audrey interview).

Essentially Audrey and the team instantiated a new rule that became a mediating tool allowing them to regularly convene and plan initiative efforts. These meetings generated ideation and collective reflection as the team analyzed feedback from the previous professional learning session and discussed any needed modifications to their approach. “I think it’s great being part of STC. It gives us the chance to actually talk about what’s happening and what went well, what didn’t go well,” (Suzanne interview).

The meetings were also a way to establish the team’s consistency in approach, problem-solve logistical and technical glitches, discuss pedagogical strategies, and share ideas for motivating non-enthusiastic peers. “We were planning what lessons we should teach; how can we push this to staff. And I think all of that was beneficial,” (Cindy final interview)

Members of the university team were also present during these meetings, so it became another avenue of communication across these teams so that they could brainstorm and strategize ways that they could support the initiative. In the latter part of the school-year, the team used the time to share the progress that they had made within their “buddy” groups.

Other Tools and Resources

Initiative Resource Page. This website became a critical tool that allowed the staff to learn more about the project goals, access resources to support integration, and other pertinent tools such as links to the coding platforms. Audrey increased its transparency by strategically embedding it within the staff resource section of the school website; a link teachers routinely accessed to complete their daily administrative tasks and for other essential resources.

Pineapple Calendar and Peer-modeling. The Pineapple Calendar was a school resource that teachers used to invite their colleagues to visit their classrooms and observe innovative lessons and teaching techniques. The team adopted it to forward their implementation efforts by posting the dates of their integrated lessons to encourage their peers to see authentic coding lessons with students.

> "I went up to see [Cindy's] lessons, so I think that was helpful that they sent out when they were doing it so I could go and see it. When I went up there, I was able to be like, okay, how did they do? What did you notice?" (SS teacher interview).
>
> "[Teacher] and I both were struggling with thinking, 'okay, what does this actually look like. So, seeing it in action I think definitely helped us visualize and feel more comfortable." (ELA teacher interview)

Social Media. Many members of the staff regularly utilized Twitter to promote and share classroom and school activities. Many of the professional learning leaders used Twitter to promote the classroom coding activities that their students were engaged in. Thus, Twitter became a communication vehicle of "positive peer pressure" (Leslie interview), as it informed the staff and wider school community of the various computing projects being implemented throughout the school.

A Resource Repository. As teachers increasingly voiced interest in finding curricular materials relevant to their own teaching needs, the team decided it would be useful to have a repository that included links to disciplinary-specific lessons. With the help of the university partners, Audrey created a database that housed existing lessons that other teachers could use and modify for their own purposes. As the teachers made new lessons and units, materials were added for everyone's view and use, as resource sharing was a highly encouraged practice by the team.

Utilizing Rules

Continuing Education Credits. The team coordinated with the district office to ensure the staff received continuing education units (CEUs) for the professional learning sessions they attended as part of the initiative. The CEUs helped to incentivize attendance at the sessions once it was no longer mandatory.

Digital Portfolios. Team members strategically aligned the initiative to meet the goals of another district-wide initiative, a digital student portfolio that required all teachers to help students upload at least one digital project that they created as part of their class that year. Audrey and Cindy (the school representative for the district portfolio roll-out team), worked with the university partners to find a means for embedding students' coding projects into their digital portfolio websites. This information was then shared with teachers at a professional learning session and a how-to-guide placed on the school initiative resource page.

Classroom Walkthrough Tool. Administration utilized a digital template to conduct "walkthroughs" of teacher classrooms at Wilton. These tools allowed the administration to document instructional practices that were valued at the school. Upon the urging of the three team leaders who were also on the school improvement team, coding and CT were added to the template as noteworthy practices.

Contradictions and Enablers

As tensions and contradictions become central to understanding an activity system, this next section discusses how the members worked to confront and resolve these various contradictions. They often did so by capitalizing on the socio-cultural and historical contexts that served as enabling elements within the activity system to further the initiative.

Lack of Communicated Expectations

Evidence revealed that staff perceived a lack of communication with regard to teacher expectations for the initiative during its first few months. The source of which was likely the absence of an agreed upon timeline between the professional learning leaders and the administration. Many of the professional learning leaders during the summer professional development were hopeful that all teachers would design and implement their own coding lessons during the upcoming school year. As such, they proceeded to work with staff as if this were the goal; however, no such mandate had come from administration. Directives regarding tangible outcomes for new school-wide learning initiatives typically came from administration, so it's likely the absence of such engendered confusion and in some instances resentment by other teachers towards the object and made them reluctant to work with the professional learning leaders. This tension was reflective of a disconnect between three components of the activity system: community (teachers), rules, and the object.

> "I don't think the expectation was made clear that we were supposed to teach one of these this year. That was kind of thrown at us and maybe created some bad feelings for some people," (ELA teacher interview).
>
> "I think what we heard was sort of like we are going to explore it and then maybe some time in the future and then it was like all of a sudden it was like you are doing this and you're doing this now," (ELA teacher focus group).

Some of the professional learning leaders recognized this disconnect and took measures to rectify it. They also realized that their original goal of wanting all teachers to implement a lesson during the current school year might have been too ambitious, given other school priorities. Therefore, they worked with the administration to present the following expectations to staff: “this year you will be given regularly-scheduled time to learn and explore the benefits of coding to teach subject-area content. You have in-school and out-of-school expertise to help you with this task and who are willing to help you develop a lesson. These individuals are willing to work with you to implement this lesson this year if you desire. Next year all staff will design and deliver a computing lesson.” Leslie, often a mediator between administration, the professional learning leaders, and other teachers, was instrumental in working with the principal to clarify and communicate those expectations formally to staff.

> “I think as the staff has realized the expectations. I think they weren’t very clear at the beginning of the year and now that we’ve kind of said, look, you’re not expected to implement this year, you’re expected to try and learn, figure it out, and then implement next year. I think that it’s gotten a lot better with them being eager to try and figure out a way to do it,” (Leslie interview).

Likewise, they were keenly aware that those expectations had to come from the administration. “They listen to [Leslie] more than they listen to me, but they still don’t listen to her like they would listen to administration. There’s just those power players that make a difference,” (Cass final interview).

Curricular Mandates

Another tension occurred between the rules, community, and object within the activity system and with competing activity systems. Teachers were reluctant to fully invest time in the initiative because of district-imposed pacing guides and state-mandated end-of-grade testing. This was particularly salient amongst math and ELA teachers who were recently charged with implementing a scripted curriculum:

“For ELA we are locked into a curriculum and we have to move through it, so ways to

> keep the rigor of that curriculum and also do coding is challenging," (ELA teacher interview).
>
> "So [Jeanine] has been trying to push me to do coding. The problem is we have so much stuff that we have to get done in a year with the new curriculum that we are mandated to do," (Math teacher interview).

Professional learning leaders worked to alleviate this tension in different ways. First, they utilized student needs for creative technology use as a lever (community-tool alignment) to convince their peers to occasionally stray from the scripted curricula.

> "I'm really excited about being able to try to and create something like that for my students. It makes it more relevant; they are all interested, and a lot of our students can't afford a lot of [technology] those things. So, their only opportunity to play with computers or technology is at school and we need to be giving them that opportunity." (Cass to her PLT during a professional learning session)

Secondly, they emphasized at professional learning sessions how coding could effectively be aligned to meet mandated curriculum objectives (a tool-rule alignment). They also encouraged low-stakes opportunities for students to learn coding (e.g., in enrichment time, as a review).

> "So, I tried to take the pressure off, and I would say, all right, there are some different things we could do. And one of the things I would suggest to them is if you're not comfortable doing it with your curriculum, try it out with your discovery [enrichment] group. They were receptive to that because there's no stakes with a discovery group. If you start like that and then, as the kids get on board with it and the teacher, get more comfortable, then you can use it as a way to introduce new concepts or create brand new

> things," (Leslie Interview).

Enabling Elements that professional learning leaders Capitalized On

Just as it is important to note the various constraints within the activity system, it is equally important to discuss components of the activity system that facilitated its expansion and how professional learning leaders capitalized upon those elements. First, professional learning leaders often emphasized the alignment between the school's STEM-focused magnet theme and the activity system object, which helped with staff buy-in.

> "We want our kids to be globally aware, we want them to be able to compete in a global world. This is what we need our kids to do. And expecting them to do, that we need to give them everything that we can. If this is our theme and this is what we're doing and we're telling you it works and kids like it, try and apply it; it's worth trying. You just have to be open to it," (Suzanne during professional learning).

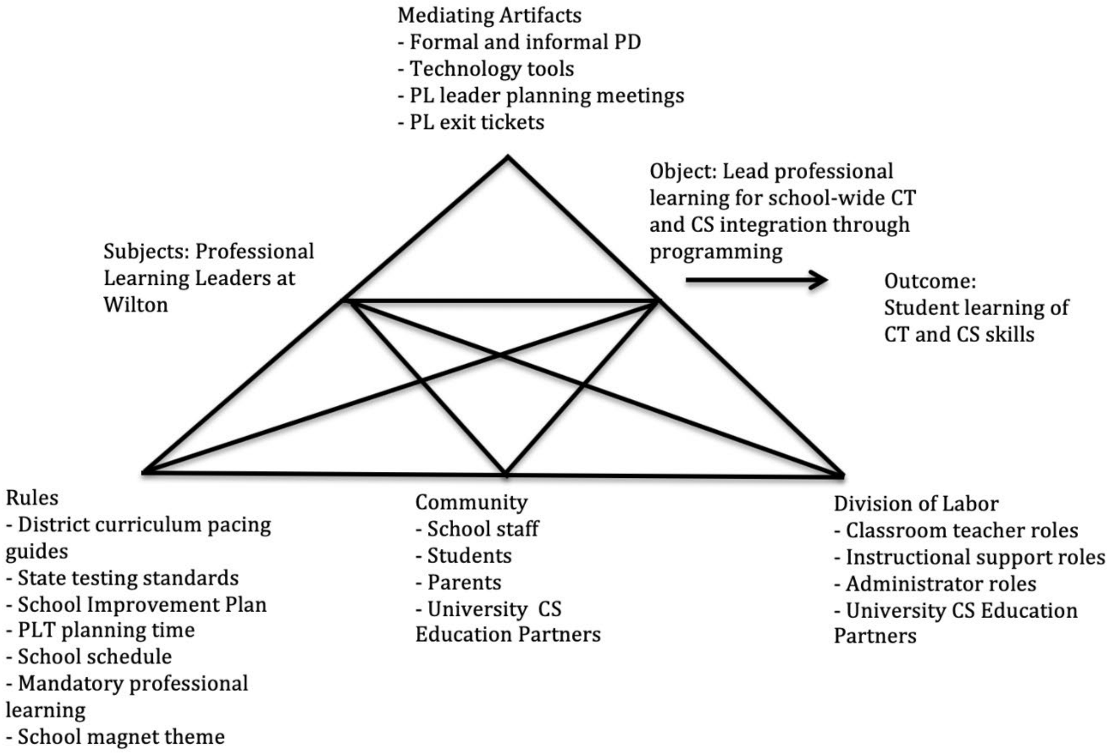
The university-based partnership, as part of the community, also helped to drive the object as the professional learning leaders and school was provided with valuable resources that otherwise would have been difficult to ascertain. In particular, the intensive summer professional development sessions for the professional learning leaders served as an important tool. First, they helped to build the team members' confidence and knowledge of CS and CT. The teachers had time and expertise from CS experts to build lessons for fall implementation that could be shared with staff and they had access to rich repositories of example projects. They borrowed and adapted slides and programming activities from the summer professional development for their leadership work at the school. They also had time to discuss and devise a plan for meeting the goals of the initiative during the upcoming school year. All of this led to more highly-resourced leaders. Additionally, the university team continued to support the leaders as they worked with teachers throughout the year, offering expertise with building new programs, be additional classroom support personnel, and setting up a server where students and teachers could easily access programming activities.

Discussion

Using a distributed, team-oriented approach to leadership, educators at Wilton were able to create a systemic support structure that promoted the adoption of a schoolwide curricular innovation, coding across the content areas. By involving multiple staff members who represented various points throughout the school's ecosystem in leadership activities, they tapped into a spectrum of local knowledge and expertise needed to shape and evolve the activity system (see Figure 4.4). Their insights into the inner workings and relationships that comprised the school's socio-cultural context positioned them to guide the initiative as they worked to build a supportive institutional culture for computing integration. Most importantly, they built a climate for professional learning within the building that extended beyond formal professional development opportunities.

Figure 4.4

Representation of the Leadership Work as an Activity System as it Evolved through the Professional Learning Initiative



It should be noted that although it was not a requirement for the current school year, twenty-two of the forty-six classroom teachers at Wilton designed and implemented an integrated Snap! coding lesson during the year. Another thirteen of the teachers had designed and developed a lesson that was ready to be taught during the upcoming school year. These numbers, as well as the overview provided in Figure 4.5 further demonstrate the effects of the professional learning leadership work. Although it is too premature to empirically measure student impacts and outcomes, because all science and ELA teachers implemented coding lessons during the current school year, all students were exposed to learning disciplinary CT and CS practices.

Figure 4.5

Scope of Collaborative Work with School Staff Over the Year

Professional Learning Leader	Peer or "Buddy" Work
Renee	• Worked with 7th grade ELA teachers to design and implement a lesson
Leslie	• Co-taught ELA lesson with Jeanine and 6th grade ELA teachers • Provided lesson design support to two elective teachers during the year
Jeanine	• Co-taught ELA lesson with Leslie and 6th grade ELA teachers • Provided lesson design support to art teacher
Audrey	• Designed and co-taught a lesson with 8th ELA teachers • Designed and co-taught a lesson with creative writing teacher • Designed and co-taught a lesson with 6th grade math teachers • With university CS team provided lesson design support to band teacher
Cass	• Supported PLT partner deliver her lesson • Provided lesson design support to 7th grade math teachers • With university CS team provided lesson design support and implementation support to 8th grade math teacher
Taryn	• Supported PLT partners deliver her lesson
Cindy	• Supported PLT partners deliver her lesson • Co-designed and co-taught lesson with Spanish teacher
Maria	• Supported PLT partners deliver her lesson • With university CS team provided lesson design support to a 6th grade science teacher
Samara	• Supported PLT partners deliver her lesson
Suzanne	• Supported PLT partner deliver her lesson • Provided lesson design support to 7th grade social studies teachers
Ashli	• Provided student support to other teachers implementing Snap! lessons during inclusion classes • Designed an anti-bullying lesson in Snap! and provided support to all teachers to implement during their enrichment class

Towards A Distributed Leadership Model for Schoolwide Computing Integration

A Multi-faceted Team Representing Various School-level Perspectives and Expertise

Prior research on school leadership and various ICT-mediated instructional reforms have underscored the importance of leadership that is distributed across the school's ecosystem

(Dexter, 2011; Dexter, 2020; Toh, 2016; Shear et al., 2014; Sun & Gao, 2019). The scope of work needed for enacting these reforms necessitates the involvement of staff throughout the school building, as it is beyond the capability of one formal leader (Hauge & Norenes, 2015). At Wilton, the leadership team involved a multitude of expertise including an assistant principal, instructional support staff, and classroom teachers across the content areas, each of whom brought a plethora of social, material, and cultural resources to the leadership activity (Spillane et al., 2003).

For CT integration to occur within classrooms, teachers need to be able to visualize explicit connections between programming and other CS practices and the learning competencies that they are required to teach (Dong et al., 2019; Kale et al., 2018b; Yadav et al., 2016b). Christensen et al. (2018) argue that school-based "learning leaders" who are "rooted in local contexts and understand the affordances for teachers and students in different content areas" are critical to successful technology integration efforts (p. 460). With deep knowledge seeded in the school and district curriculum and the pedagogical needs of the student population, the classroom teachers on the team were rich sources of expertise needed for teacher buy-in (Hestness et al., 2018).

Instructional support specialists such as technology coordinators and media specialists have long since played a historical role in leading and supporting school technology innovations (Dexter et al., 2009; Dexter, 2011). This study demonstrates that these school personnel should continue to have a place in CT/CS integrated initiatives as well. As teachers become faced with technology access challenges related to technical and logistical problems, these individuals can become valuable sources for relieving those types of tensions. Likewise, the magnet coordinator and assistant principal had the footing to secure resources and routines that required the principal's endorsement.

Leadership Practices Must Be Responsive to the Needs of the Local Context; the Development of Such Practices Should be an Ongoing and Iterative Process

Because leadership is spread over "an interactive web of people and situations," school leadership practices need to be responsive to the actions of teachers and the evolving nature of the school's "organizational routines, structures, and tools" (Spillane, 2005, p. 144). During the summer, the team at Wilton only began to etch an outline of potential facilitating conditions that could promote the adoption of instructional innovation at the school. They met regularly thereafter during the school year to further develop and refine tools, routines, and structures, collectively designing leadership practices that supported the school-wide adoption of computing.

Technology initiatives inevitably cause tensions and contradictions as teachers are confronted with adopting new tools and pedagogical practices and reconciling how to fit those within their existing teaching contexts and realities (Howard & Gigliotti, 2016; Karasavvidis, 2009; Reichert & Mouza, 2018). Although there were challenges along the way, the team utilized their local knowledge to align and realign various components of the ecosystem that were in flux to relieve tensions and foster "ecological coherence" (Toh, 2016, p. 165), allowing the activity system to develop and expand (Engeström, 1987/2015).

If the professional learning leaders had planned and structured the professional learning at the outset, they would have missed important opportunities to differentiate and meet teachers' current levels of readiness to explore. Given CT/CS is a novel concept to many teachers (Garvin et al., 2019; Sands et al., 2018), leadership practices to encourage its integration should grow organically as leaders respond to followers and the situation (Spillane, 2006). The team at Wilton accomplished this by devoting time to develop their leadership practices by meeting and reflecting on various feedback loops (e.g., teacher surveys, anecdotes, work with peers) from within the community (e.g., teachers, students, university partners). This enabled them to be responsive to teachers' needs and adapt their leadership practices based on those needs and the activity system as it evolved. For instance, they realized that they needed a directive from the principal to make expectations clear to staff about implementation because that was an established institutional norm. Thus, they worked with the hierarchical structure rather than against it, using their leadership practices to get expectations clarified.

Foster a Culture of Learning through a Supportive Climate with Formal and Informal Professional Learning Opportunities

A school climate replete with collegial support and expertise is a central factor for successful teacher technology integration (e.g., Ermer et al., 2015; Karaca et al., 2013; Li & Choi, 2013; Vermeulen et al., 2017). Thus, building a framework of peer support that consisted of both formal and informal opportunities for teacher learning was one of the most noteworthy leadership practices that the Wilton team engaged in. Specifically, they integrated essential elements of social capital (e.g., peer support, trust, and access to expertise) (Li, 2010), while employing best strategies for professional learning such as peer collaboration, hands-on, and differentiated learning that extended across the school year (Yurtseven Avici et al., 2018). By combining these, the team at Wilton provided a comprehensive network of expertise and learning opportunities for teachers throughout the building.

Regularly scheduled, formal professional development sessions helped to lay foundational paths for teachers' professional growth with coding integration. A shared focus was established (Christensen et al., 2018), by devoting these monthly sessions to the topic, as teachers collaborated in small, disciplinary groups to explore and experiment. Later in the year, teachers were provided with mentor "buddies" during these sessions to help plan, design, and deliver lessons. Inasmuch as the regularly scheduled, formal professional development sessions were important components, the informal learning offered by team members also contributed to much of the staff's success. This included but was not limited to inviting teachers to observe professional learning leaders model lessons, provide resources that allowed for self-exploration, and engaging colleagues in casual conversations during PLTs and in the break room.

Similar to findings from Israel et al. (2015), we witnessed more teachers willing to try and implement their own lessons with students once they became confident they had institutional support and expertise. This reiterates the importance of collegial trust and established relationships as vital elements of social capital that can be leveraged to engender teacher buy-in (Li, 2010; Li & Choi, 2013). While never being mandated for the current school year, by the early spring (when the school year changed to remote learning because of COVID-19), approximately half of the staff had implemented a coding lesson within their classroom.

Conclusion

With the increasing recognition that CT and CS should be a regular part of learning for every student, schools will be tasked with creating strategies for effective integration. Fully integrating CT/CS into disciplinary learning will take intensive leadership efforts at the school-level that can be led by expertise within those buildings. This study enabled a distinct opportunity to elicit what a potential professional learning leadership model for computing integration could like and the types of leadership work that these individuals must engage in.

When schools invest in building the capacity of a small group of educators, they can then mine this social capital to diffuse the knowledge and expertise throughout the building.

This study helps to fill a gap in the literature on effective technology leadership in schools, in particular for CT/CS integration and suggests that a new conception of school leadership beyond administrative directives may be needed.

Chapter 5: Discussion

This chapter offers a summary and discussion of each research study, including their their scholarly and practical implications. This is followed by a more in-depth discussion of the limitations of the research, future research in this area, and concluding thoughts.

Summary of Chapter 3

The first study was motivated by the need for a validated instrument to measure teachers' self-efficacy for teaching CT. Therefore, self-efficacy, as conceptualized by Bandura (1977, 1997), was chosen as the appropriate theoretical framework to develop such an instrument. The T-STEM CT's twenty, Likert-type items were informed by items on a previously validated instrument that measures teachers' self-efficacy for teaching the various STEM disciplines (Rachmatullah et al., 2019).

The instrument development process was guided by the *Standards for Educational and Psychological Testing* (AERA et al., 2014) and included an iterative process of expert review and cognitive interviewing. Then, using data collected from a sample of in-service teachers, evidence of reliability and validity on the internal structure of the T-STEM CT was ascertained. Overall, the quantitative analyses demonstrated that the T-STEM CT is a theoretically sound and reliable instrument to measure in-service teachers' self-efficacy for teaching CT. Ultimately, the instrument development process and validation work for this study resulted in a tool that can be used by researchers and in-service teacher educators.

Prior literature has shown that teachers' self-efficacy for technology use and integration is important for student success with technology (Anderson et al., 2011; Ertmer & Ottenbreit-Leftwich, 2010; Holden & Rada, 2011; Lui et al., 2016). Likewise, teachers' self-efficacy for teaching disciplinary content is believed to be a critical component for effective student learning

(Allinder, 1995; Cantrell et al., 2013; Pamuk et al., 2017; Tschannen-Moran et al., 1998). Therefore, this study is grounded in the belief that high levels of teacher self-efficacy for teaching CT is a critical and necessary component for teachers to create rigorous CT learning experiences for students. Although recent studies suggest that teachers lack comfort and confidence in CT (Cateté et al., 2018; Israel et al., 2015), this is difficult to assess empirically without a robust instrument. This study contributed to such a tool that can be used by both researchers and practitioners. As such, the T-STEM CT has potential value for both practical and scholarly applications.

For both researchers and practitioners, a greater understanding of teachers' beliefs and attitudes such as self-efficacy towards technology and technology use results in better-designed resources and support (Ertmer et al., 2012; Unger & Tracey, 2013) which has pragmatic implications for the use of the T-STEM CT. Albion et al. (2015) assert that teachers' pedagogical beliefs towards ICT use "should be considered as major foci in any approach to teacher professional development" (p. 658). Accordingly, professional development designers could administer the T-STEM CT as a pre-assessment tool to then inform the design of professional learning experiences so that they are customized and address teachers' individualized needs and comfort levels (Ertmer et al., 2012; Harris, 2008).

Likewise, Tondeur et al., (2017) argue that research on technology innovations and integration "can only be fully understood when teachers' pedagogical beliefs are taken into account" (p. 556), as these beliefs influence their instructional decision-making. Therefore, when investigating the integration of CT in teachers' instructional practices, researchers will need instruments that enable them to consistently assess teachers' self-efficacy levels with CT. Equipped with these metrics, researchers will be able to synthesize findings across various studies for a fuller understanding of the phenomenon (Tang et al., 2020). In this manner, the T-STEM CT has scholarly implications as well.

Summary of Chapter 4

The study presented in chapter 4 sought to elicit how new leadership roles for educators at one school were instantiated to implement a school-wide professional learning initiative on CT integration with Snap! coding. To do this, an instrumental case study approach was employed to qualitatively delve into the deep nuances of this leadership work. The case was bounded by the leadership work of these educators at this middle school as a distinct activity. This strategy enabled a holistic view of the interactions of the complex socio-cultural variables and a richer understanding of the participants' experiences.

The study utilized a distributed leadership framework (Spillane, 2006) to investigate the leadership practices of the participants at the school and applied CHAT as an analytical lens to evaluate those practices as situated within the complex socio-cultural factors of the school context (Engeström, 1987/2015). Therefore, the professional learning initiative as led by this group at the school was considered the activity system under investigation. The study found that by using a distributed approach to leadership, the professional learning leaders were able to create a school-wide support structure that promoted classroom teachers' adoption of coding within their content areas. Collectively, the team had intimate knowledge of the school's socio-cultural context which positioned them to build a supportive institutional culture for computing integration. This included providing professional learning opportunities for teachers at the school that were characteristic of effective professional development in that it was site-based, ongoing, authentic, and took differentiated approaches to meet teacher needs (Desimone & Garet, 2015; Penuel et al., 2007). Ultimately, the study offered a model for schoolwide computing integration based on the tenets of distributed leadership (Gronn, 2000; Spillane, 2006), and best practices for effective teacher professional learning.

Viewing the team's leadership work as a distinct activity system and analyzing it with the various components of CHAT enabled a more nuanced understanding of the professional learning leaders themselves, their efforts, and the interplay of those efforts as a part of the larger school ecosystem (Hirsh & Segolsson, 2019; Ho et al., 2016). This integrated analysis was then used to answer the larger overarching research question, 'How do a team of educators at one middle school collectively lead a professional learning initiative on computing integration within their school?' The results section described their actions and interactions with various members of the activity system (e.g., school staff, university CS team) that characterized their leadership work.

By analyzing the professional learning leaders as subjects who instantiated various tools and norms as part of their individual and collective leadership practices across the school community, the second research question, 'How are leadership practices distributed amongst the team and within the larger school context?' was answered. Through this analysis, it became apparent that the team's diversity (e.g., classroom teachers, administrator, instructional support staff) enabled them to distribute their efforts more efficiently. For example, the classroom teachers utilized their teaching and disciplinary expertise to work closely within their professional learning teams. This is an important strategy for CT integration as prior research indicates that non-CS teachers need to see explicit connections between CT and their disciplinary content areas (Dong et al., 2019; Kale et al., 2018b; Yadav et al., 2016b). Alternatively, the other members of the professional learning team garnered community stakeholder support and provided overall leadership direction for the team. This finding resonates with research on other school-wide technology integration initiatives which have emphasized the value that non-teaching staff members can contribute to such leadership efforts (Dexter et al., 2009).

Finally, viewing their practices against the backdrop of the school's larger socio-cultural context allowed for the broader understanding needed to answer research question three, 'What aspects of the situation (context) enable or constrain the leadership practices?' Equipped with this greater contextual understanding of where the leadership work was executed, enablers and constraints to their work were illuminated. Additionally, depictions of how the professional learning leaders used their practices to overcome constraints or capitalize on these enabling factors were provided. Uncovering tensions that arise within an activity setting and how those constraints are resolved are important to determine if they become opportunities for expansive learning that evolve the activity system (Engeström, 2001).

As more non-CS teachers are tasked with designing computationally-rich learning experiences for their students, viable professional learning models that support these integration practices are necessary. This study resulted in recommendations for a distributed leadership model to support school-wide integration. Thus, these recommendations can be considered strategies for schools and districts who wish to design similar school-level support models. Likewise, researchers need to continue rigorously documenting and analyzing how CT is taught and integrated within schools (Israel et al., 2015). This study demonstrated that CHAT offers researchers a sound theoretical and analytical framework for capturing the complexity of the school environment and the multitude of variables that impact how CT is integrated within schools.

Revisiting A CHAT Perspective for Computational Thinking Integration

As I worked on this research utilizing a CHAT theoretical framework, I began to glean some new insights with regards to the integration of CT and the various components of CHAT. Additionally, I began to see a vital connection between elements of both studies — the importance of teacher self-efficacy for CT. First, there is an apparent overlap between self-efficacy for teaching CT as being a trait of the subject, or in this context the teacher, and its role as a mediating artifact that influences the teacher's actions towards the object. This exemplifies the complex interplay of variables that can occur within a distinct activity system (Barab et al., 2004; Engeström, 1999). Although self-efficacy is an intrinsic or teacher-level trait that is inherent to the subject, it also becomes a tool that teachers need to effectively teach and integrate CT. In short, teachers must believe in their own capabilities to do so and that if they do, their actions will result in positive results for their students (Bandura, 1997), who are an integral part of the community as conceptualized through CHAT.

This has implications for the second research study, as schools look to build sustainable models that support teachers as they integrate CT into their classroom practices. It will be important for professional learning leaders at these schools to not only provide training on CT and CS skills, but also to design resources and support structures that nurture the growth of teachers' self-efficacy in this disciplinary area. Figure 5.1 offers a CHAT perspective for specifically building teacher self-efficacy for teaching CT. Table 5.1 provides examples to illustrate the complex interplay amongst various mediating factors within the activity system.

Figure 5.1

A CHAT Perspective for Building Teacher Self-Efficacy for Teaching CT

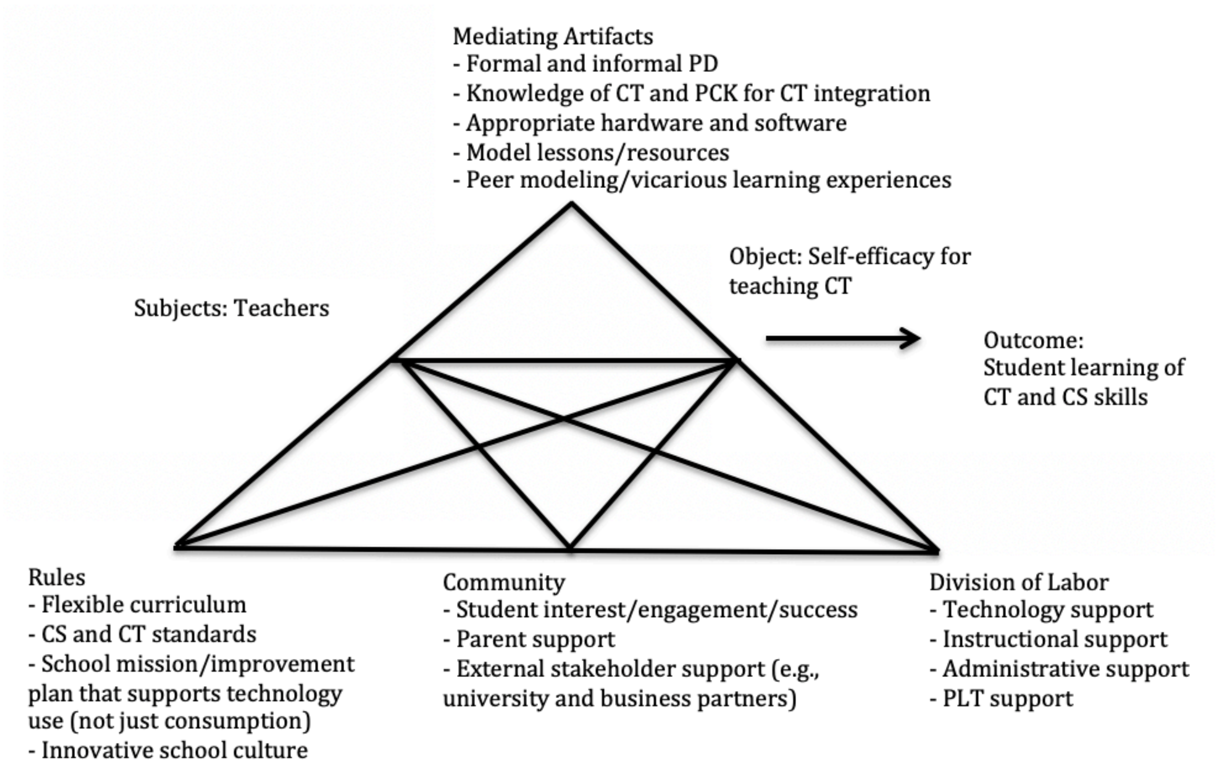


Table 5.1

Selected Examples of Factors that Mediate Teacher Self-Efficacy for Teaching CT and their Inter-relationships

Mediating Factor	CHAT Component	Relationship to other factors within the Activity Setting
Technology Support	Division of Labor (DOL)	- Teachers need access to adequate and functioning technology (Tool); school personnel can provide this. - When technology malfunctions it can diminish mastery experiences needed to grow teacher self-efficacy (Subject). - A school improvement plan that promotes technology use will allocate the tools and personnel support needed (Rules).
Professional Development (PD)	Mediating Artifact/Tool	- Teachers need PD to build their knowledge of CT and PCK for CT integration (Subject). - Supportive administrators (DOL) will allocate the time necessary (Rules) for PD.
PLT Support	Division of Labor	- Through PLT support teachers can get subject-specific resources (Tool) such as model lessons and peer modeling. - School administration (DOL) must provide opportunities for PLT work (Rules) within the school culture.
Curriculum	Rules	- Administrators (DOL) and parents (Community) who support the integration of CT and CS as part of the curriculum, encourage teachers to build their capacity for CT integration (Subject).
Students	Community	- Engaged students can motivate their teachers (Subject) to integrate CT. - Students must have opportunities to use innovative technology (Tools). - An innovative school culture (Rules) and administration (DOL) will promote technology for authentic and engaging learning experiences.

Another important finding from this work that cannot be underestimated is the critical role that rules play in a school context. Feedback from teacher participants revealed that one of the biggest obstacles or tensions within this activity system was the curricular restraints that teachers contended with. District pacing guides and state end-of-grade tests restrict the freedom and agency that teachers have in deciding the curricular materials that they use within their own classrooms. This reflects a competing activity system that makes K-12 CT and CS integration even more challenging. Although Barr and Stephenson's (2011) was published almost a decade ago, it is clear that continued collaboration between the CS education community, teachers and policy-makers must occur to enact the systemic change necessary to prepare our youth for the future.

Lessons Learned: RPPs and Distributed Leadership for CT Integration

From a practical standpoint, this study offers some lessons learned and best practices to others who may be looking to establish a similar initiative at their school or district. These practices also have implications for researchers and practitioners' work as they engage in research-practice partnerships that focus on CS integration.

Implications for RPPs

Research-practice partnerships are now recognized as viable strategies for achieving a variety of educational outcomes (Coburn & Penuel, 2016). Lessons learned from this study can guide those who wish to leverage school-university partnerships to promote innovative school-wide pedagogical practices, such as CT and CS integration. Although RPPs focus on problems of practice of mutual interest to researchers and practitioners alike, teacher buy-in can still be challenging as it often presents a disruption to established traditional instructional practices (Coburn et al., 2013). Although our team established an RPP to address a problem of practice aligned with the school's mission and therefore, in the best interest of all school stakeholders, large scale teacher buy-in did not occur until we involved classroom teachers through distributed leadership practices.

During the first year of the RPP, university researchers were primarily engaging the principal, magnet coordinator, and select science teachers who were implementing lessons the researchers had developed. As a result, the CT/CS integration work was limited in scope, and it was not until the work of the professional learning leaders that we witnessed widespread buy-in. Therefore, to fully engage the entire staff, it is recommended that classroom teachers become involved early on in leadership work related to the RPP goals. Additionally, because of the summer professional development and the regular coordination with the CS education researchers, the professional learning leaders had a greater understanding of the goals of the RPP. Therefore, they were able to act as brokers to carry out the RPP work with other staff members (Penuel et al., 2015).

Teacher Leadership

Albeit, all of the professional learning leaders had unique contributions to the initiative, the involvement of the classroom teachers on this team was a critical component for success. First, it allowed teachers to see authentic integration in classrooms, as well as how lessons could be aligned to fit in with curricular mandates. Additionally, their peers on the leadership team became role models as they took pedagogical risks and became sources of vicarious learning for the other teachers at the school. These results align with prior literature that tout the importance of school-level teacher leadership (e.g., Berry, 2019, Katzenmeyer & Moeller, 2009). Therefore, engaging classroom teachers in this work is a recommended crucial component.

Representation across Subject Areas

This study also found that teachers were even more motivated to engage in the integration work when they had a member of their subject-area PLT on the professional learning leadership team. Unfortunately, we did not have equal representation across subject areas, which became a detriment to the efforts. This past year the RPP had initially asked for volunteers. However, it may make more sense to have an application process where teachers can describe their commitment and willingness to lead innovation, and the RPP team can decide who would be best suited to lead the efforts. This process would also help to ensure that expertise is spread evenly amongst subjects and grade levels. Because we had been working with science teachers for a few years prior, we ended up with more science teachers on the professional learning leadership team than any other subject. As a result, the science professional learning leaders had fewer opportunities to exercise and grow their leadership skills, and other subject areas did not have as much expertise to rely on within their PLTs.

We also witnessed uneven levels of growth and commitment from the professional learning leaders. While some were eager to experiment with new pedagogical and technical skills and share these new skills with colleagues, a few struggled to extend their skills within and beyond their classroom. Also, because rapport and respect amongst one's colleagues were an important tool of influence, it is essential that those on the leadership team are already well-respected as classroom teachers. Having an application process can help to mitigate these potential problems.

Administrative Support

Finally, this initiative experienced success because of the mindset and commitment of the school administration. Administrative buy-in had already been established through the RPP; therefore, the principal trusted the university team's work at the school and ultimately supported the idea of a distributed leadership model to lead the initiative. The administration also regularly encouraged teachers and other staff to take on leadership roles at the school to help direct a variety of initiatives (e.g., the school improvement team, the positive behavior support team). They also encouraged teachers to take risks and try innovative teaching practices within their classrooms, which helped make teachers feel more comfortable trying to integrate coding within their curricula.

Limitations

Like all research, the studies that comprise this dissertation each have their own limitations that should be considered as the results from these studies are interpreted. For the first study, there are limitations due to the relatively small final sample size (N = 318). First, it was not possible to conduct a cross-validation study where the data set could be randomly split in half to first conduct an exploratory factor analysis and then proceed with a CFA on the remaining half (Thompson, 2004). Additionally, although participants were recruited from list-servs and social media outlets that tried to reach individuals across the U.S., a majority of the participants were from North Carolina. It was also beyond the scope of this study to ascertain multiple forms of validity evidence such as convergent and criterion-related validity evidence (AERA et al., 2014; Messick, 1995). In addition, it is unknown how the T-STEM CT stands as a measure to assess performance over time with evidence of test-retest reliability (Huck, 2000), as it was administered to participants in this study on only one occasion.

There are also limitations related to the design of the survey which relies on self-reported data. With self-report data there is always a risk of participants misreporting (Tourangeau et al., 2000). In addition, because the items on the T-STEM CT require respondents to self-report their ability to teach CT in a broad sense, results from the measure will reflect each individual teacher’s definition of CT. Thus, findings from the measure should be interpreted with this in mind. To avoid such ambiguity, it is recommended that anyone who uses the instrument should provide respondents with a working definition of CT that clearly reflects what they wish to measure.

The design of the second research study also engendered limitations that should be discussed. First, this study took place at one middle school that had a STEM-focused magnet theme. Therefore, findings from this study may not be readily generalizable to other school contexts and the school's focus may have been a factor that contributed to teachers' willingness to adopt the innovation. Second, the professional learning goals included a very narrow focus of CT/CS integration—coding—and it would be interesting to compare initiatives that focused on other mechanisms for CT integration (e.g., robotics, makerspaces). Also, the professional learning leaders received extensive external professional development provided through their university partners. This professional development was designed with the goal that these individuals would lead their peers during the school year. Other schools that wish to employ such an initiative will also need to seek appropriate external professional development to ensure that professional learning leaders receive the foundational knowledge needed to lead their colleagues. Third, because only one researcher initially coded the data, inter-rater reliability was not calculated and reported for this report. Finally, this study occurred during just one academic year, and the investigation focused on initial leadership practices enacted to build a foundation for the initiative. A longitudinal study is underway to determine how the initiative and related leadership work continue to evolve and eventually to investigate its impact on students. It is also important to note that due to the COVID-19 pandemic, the school year prematurely transitioned to remote learning. Thus, the remaining two scheduled professional learning sessions never occurred. It is worth mentioning that a few of the teachers worked with the media specialist to deliver the lessons that they had developed to students online.

Future Research

The aforementioned limitations of each study also present opportunities for future research on supporting teacher CT integration practices. Instrument development is an evolving process (AERA et al., 2014) and this was the first study examining the reliability and validity of the T-STEM CT. Thus, work to further validate and refine the instrument should continue to address some of the limitations noted within this specific study. Replicating the study and collecting additional responses is needed to ascertain additional evidence of validity and to test the instrument with new and more varied participant populations. Relatedly, another potential avenue for future research with the T-STEM CT is to conduct a study with pre-service teacher populations to determine if it has utility for teacher educators. However, in all future administrations of the survey, it is recommended that the item order within each factor is randomized to determine whether the contextual effects that produced correlated nonrandom errors within the model are mitigated.

Additional research can help establish convergent and discriminant validity, criterion-related validity, as well as furnish more evidence of construct validity. In particular, item response theory (IRT) has gained notoriety as a precise methodological tool for robust validation work (Bond & Fox, 2001; Reise et al., 1993). Therefore, CFA, in combination with IRT methods such as Rasch modeling, could also enhance the validity evidence for the T-STEM CT. Of particular interest is the application of IRT methods such as differential item functioning to establish additional fairness standards to ensure survey items are not functioning differently for individuals from various subgroups.

Future studies should also administer the instrument as a pre- and post-measure at various CT-related professional learning opportunities for in-service teachers to determine test-retest reliability. Once the T-STEM CT is deemed reliable as a pre- and post-assessment instrument, it can be used by researchers and practitioners to determine the effectiveness of interventions that aim to increase teacher's confidence in teaching CT, furthering research that focuses on the evaluation of intervention strategies. The T-STEM CT can also be used in conjunction with other methodological approaches such as structural equation modeling and regression models to investigate various factors that may influence teachers' self-efficacy for CT and its relationship with other variables. For example, participant results from the T-STEM CT along with measures of prior CT and CS experiences, knowledge of CT and CS, as well as demographic variables could reveal the complex interrelationships amongst these variables.

The second study was an instrumental case study that focused on the phenomenon as it transpired in one school. Yin (2014) argues that applying replication logic through multiple case studies is an important strategy for increasing the external validity of a study. Furthermore, multiple case studies extend the generalizability of findings and support the propositions derived from a single case (Yin, 2014). Future research needs to be replicated across multiple schools, including elementary and high schools, to determine the extent that various contextual factors influence the type of leadership work executed by the participants in this study.

This second study also opens the door for mixed methods research studies, where quantitative data measures are integrated within the case study design to study the phenomenon of interest (Creswell & Plano-Clark, 2011). The addition of quantitative data sources such as the T-STEM CT could enable a more robust case study approach, where the quantitative data findings could serve either as an exploratory phase or as triangulating evidence for the qualitative findings (Creswell & Plano-Clark, 2011). Because the relationship between pedagogical beliefs and technology use are believed to be bi-directional (Tondeur et al., 2017), a longitudinal study that investigates the impact of a similar professional learning initiative led by school educators over more than one year could yield important findings about how teachers' beliefs about CT are reconstructed over time. Furthermore, extending this research over time to assess the impact of the professional learning intervention on school-wide student outcomes would be a valuable contribution to the CS education research community.

Concluding Thoughts

The purpose of this research was to offer practical and scholarly contributions that would support K-12 non-CS teachers' CT integration practices. Larger motivational goals for the research was born out of a variety of recent educational, economic, and social trends that have become recognized over the past several years. First, the use of computational tools and practices are now considered vital skill sets of essence to many professionals as they support innovation across a variety of industries (Education Policy Committee, 2014; Webb et al., 2017). Furthermore, the ubiquity of computing in our personal lives necessitates that all individuals not only consume technology but are also able to safely use computing for communication, collaboration, creation, and problem-solving (Mishra et al., 2013; Sanford & Naidu, 2016). Knowing that historically large segments of the population have been left out of CS and other STEM-disciplines, providing all students opportunities to build these skills has never been more critical (Barnes & Thiruvathukal, 2016; Margolis et al., 2008).

As researchers, educators, and policy-makers have come to recognize CT and CS as core skills that should be accessible to all (Wing 2006, 2008; Grover & Pea, 2013, 2018), many now agree that one of the most effective and equitable ways to achieve this is by exposing students to these practices early and frequently during their K-12 learning trajectories (Kale et al., 2018b; Manilla et al., 2014; Yadav et al., 2016b). In fact, several states have begun the process of establishing CT and CS standards across the K-12 learning expanse (Code.org Advocacy Group, 2019). However, this now necessitates effective modes of teacher interventions as many in-service teachers have never had any formal training on CT or CS integration within their subject-area disciplines (Corradini et al., 2017; Garvin et al., 2019; Sands et al., 2018). Even though teachers play key roles in providing their students with robust and authentic opportunities to learn CT and CS, teachers face many barriers in meeting these goals including the appropriate knowledge, skills, and attitudes to design and deliver these learning experiences (Catete et al., 2018; Israel et al., 2015; Kale et al., 2018a). The two studies in this dissertation were each designed to play a unique contribution to further the work to date in this area. These studies and their related findings add to the scholarly work to find effective strategies that prepare K-12 teachers to teach and integrate CT into their regular disciplinary practices. Although there are limitations noted for each study, as discussed above, these limitations also present opportunities for future research in these areas.

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APPENDICES

Appendix A - T-STEM CT Survey Instrument

DIRECTIONS:

For each of the following statements, please indicate the degree to which you agree or disagree. Even though some statements are very similar, please answer each statement. There are no "right" or "wrong" answers. The only correct responses are those that are true for you. Whenever possible, let the things that have happened to you help make your choice.

Computational Thinking Teaching Efficacy and Beliefs

Directions: Please respond to these questions regarding your feelings about ***your own*** teaching.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1. I am continually improving my computational thinking teaching practice.	○	○	○	○	○
2. I know the steps necessary to teach computational thinking effectively.	○	○	○	○	○
3. I am confident that I can explain to students how computational thinking works.	○	○	○	○	○
4. I am confident that I can teach computational thinking effectively.	○	○	○	○	○
5. I wonder if I have the necessary skills to teach computational thinking.	○	○	○	○	○
6. I understand computational thinking concepts well enough to be effective in teaching computational thinking.	○	○	○	○	○
7. Given a choice, I would invite a colleague to evaluate me teaching computational thinking.	○	○	○	○	○
8. I am confident that I can answer students' questions about computational thinking.	○	○	○	○	○
9. When a student has difficulty understanding a computational thinking concept, I am confident that I know how to help the student understand it better.	○	○	○	○	○

10. When teaching computational thinking, I am confident enough to welcome student questions.	○	○	○	○	○
11. I know what to do to increase student interest in computational thinking.	○	○	○	○	○

Computational Thinking Teaching Outcome Expectancy

Directions: The following questions ask about your feelings about teaching ***in general***. Please respond accordingly.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
1. When a student does better than usual in computational thinking, it is often because the teacher exerted a little extra effort.	○	○	○	○	○
2. The inadequacy of a student's background in computational thinking can be overcome by good teaching.	○	○	○	○	○
3. When a student's learning in computational thinking is greater than expected, it is most often due to their teacher having found a more effective teaching approach.	○	○	○	○	○
4. The teacher is generally responsible for students' learning in computational thinking.	○	○	○	○	○
5. If students' learning in computational thinking is less than expected, it is most likely due to ineffective computational thinking teaching.	○	○	○	○	○
6. Students' learning in computational thinking is directly related to their teacher's effectiveness in teaching computational thinking.	○	○	○	○	○
7. When a low achieving child progresses more than expected learning computational thinking, it is usually due to extra attention given by the teacher.	○	○	○	○	○
8. If parents comment that their child is showing more interest in computational thinking at school, it is probably due to the performance of the child's teacher.	○	○	○	○	○

9. Minimal student learning in computational thinking can generally be attributed to their teachers.	○	○	○	○	○

Appendix B - Interview Protocol for Professional Learning Leaders

Pre-PD Interview

1. Tell me a little bit about yourself professionally including your role at [School].
2. Can you share what motivated you to volunteer to be a teacher leader with CT integration at your school next year?
3. Can you describe any previous school leadership roles that you have held either at [School] or other schools?
4. How would you define computational thinking?
5. What prior experience do you have integrating CT and CS into your classroom practices?
6. How have you supported student learning during these activities?

During PD

1. What sessions and/or activities were most helpful? Why?
2. Was there anything that you participated in that gave you new insights into computational thinking integration?
3. Was there anything that you participated in that gave you new insights into how to support your students' learning with integrated computational thinking?
4. Was there anything that you learned that you would like to share with your colleagues in the fall? If so, why?

Post-PD Survey or Interview

1. At this point, how confident are you that you will be able to design and deliver CT integrated lessons in the fall?
2. What dispositions and skills do you think will be most important for you to effectively facilitate student learning in these activities?
3. At this point, what are your ideas for working with your colleagues in the fall to integrate computational thinking?
4. What dispositions, skills, and knowledge do you think will be most important for you to possess as a teacher leader for integrated CT?
5. Do you anticipate any obstacles to being a teacher leader for integrated CT at your school?
6. What kind of support do you feel you would need to fulfill the CT teacher leadership role?
7. How would you define computational thinking?

Monthly Check-In

Classroom Practices/Student Learning

1. Can you describe the progress you have made with CT integration so far?
2. What have you learned? (Big takeaways)
3. What challenges do you still have with CT integration?
4. What supports do you need to overcome these challenges?
5. Were you able to leverage anything from the PD this summer to help you?

6. How successful do you think you were in implementing the techniques emphasized in the CT integration PD?
7. What barriers did you encounter as you tried to implement the CT lessons?

Leadership

1. Can you describe any opportunities that you've had to work with your colleagues this past month on CT integration?
2. (If **no,** follow with:) Can you tell me why you have not been able to?
3. (If **yes,** follow with:) What kind of feedback have you received from the teachers who have implemented integrated CT?
4. Have you been able to exercise any teacher leadership since we've been back in school?
5. Do you have any upcoming plans or ideas to work with colleagues?
6. (If **yes**, follow with:) Can you tell me about it?
7. Have you encountered any obstacles in this leadership work?
8. What do you perceive as helpful or supportive to carrying out this role?
9. What components of the professional development, if any, have you been able to leverage to execute this collaboration with your colleagues?
10. Have any of your colleagues from the teacher leader cohort been helpful?
11. Have the MTAC meetings been helpful?

Final Interview

1. I'd like you to reflect on your teacher leadership efforts with CT/CS integration this year.
2. What do you think has gone well?
3. What would you like to improve on?
4. What do you think your role has been?
5. How has the DST been?
6. Anyone in the group stand out to you?

Appendix C - Interview Protocol for School Administrators

What are your perceptions about how the teacher leadership w/ Snap coding is going?

How do you think other teachers are receiving it?

What do you think is effective about it?

What do you think needs improvement?

What do you think are the most important elements to make it successful?

What are some initial thoughts about some of the teacher leaders' efforts? Has anyone's efforts stuck out to you in particular?

What about classroom teachers?

If we were to do an application process next year, what do you think would be some qualities or requirements we would want specify?

Do you think it's a good idea? Why or why not?

Appendix D - Interview Protocol for School Staff

What do you think about the Snap coding school-wide PD that has been happening?

Have you been able to make any progress?

If so, what has been helpful? (Person, resources)

If not, what support do you still need?

Appendix E - Exit Ticket for Professional Learning Sessions

What did you like about today's professional development?

Share some progress that you made today.

What do you still need help with to implement a coding lesson in your classroom?

What could be improved for the next Tech Thursday professional development?