Original Research Article

Preparing Special Education Preservice Teachers to Teach Computational Thinking and Computer Science in Mathematics

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Emily C. Bouck[1], Phil Sands[1], Holly Long[1], and Aman Yadav[1]

Abstract

Increasingly in K–12 schools, students are gaining access to computational thinking (CT) and computer science (CS). This access, however, is not always extended to students with disabilities. One way to increase CT and CS (CT/CS) exposure for students with disabilities is through preparing special education teachers to do so. In this study, researchers explore exposing special education preservice teachers to the ideas of CT/CS in the context of a mathematics methods course for students with disabilities or those at risk of disability. Through analyzing lesson plans and reflections from 31 preservice special education teachers, the researchers learned that overall emerging promise exists with regard to the limited exposure of preservice special education teachers to CT/CS in mathematics. Specifically, preservice teachers demonstrated the ability to include CT/CS in math lesson plans and showed understanding of how CT/CS might enhance instruction with students with disabilities via reflections on these lessons. The researchers, however, also found a need for increased experiences and opportunities for preservice special education teachers with CT/CS to more positively impact access for students with disabilities.

Keywords

high-incidence disabilities, teacher beliefs, teacher knowledge, assistive technology, teacher preparation practices and outcomes

Computational thinking (CT) and computer science (CS) are two terms increasingly used in society and education, but often still cause confusion for educators (Cabrera, 2019; Yadav et al., 2018). A commonly accepted definition of CT is "solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science" (Wing, 2006, p. 33). CT involves big CS principles, such as abstraction (i.e., focusing on needed information and ignoring unnecessary), algorithms (i.e., step-by-step parts of a task), debugging (i.e., identifying and fixing errors), decomposition (i.e., breaking a task into smaller, more manageable parts), and patterns (i.e., similarities and repetitions in things; Grover & Pea, 2013; Wing, 2006; Yadav et al., 2016). CT does not necessitate the use of computing tools; rather, it is a process by which individuals can approach novel challenges and

[1]Michigan State University, East Lansing, USA

Corresponding Author:
Emily C. Bouck, Michigan State University, 620 Farm Lane, 343A Erickson Hall, East Lansing, MI 48824, USA.
Email: ecb@msu.edu

consider how they might best be solved using techniques related to those within the world of CS (Hunsaker, 2020). While scholars suggested CT as a set of problem-solving strategies that computer scientists engage in, CS itself is "the systematic study of algorithmic processes that describe and transform information: their theory, analysis, design, efficiency, implementation, and application" (Denning et al., 1989, p. 12). CS involves other aspects of computing, such as hardware design, artificial intelligence, and robotics; it is not limited to coding (Mason & Rich, 2019).

In recent years, attention to CT/CS has increased in K–12 education (Araujo et al., 2019; Mason & Rich, 2019). Despite the general interest in CT/CS, teachers still need to gain a greater understanding of what CT and CS are, how to teach both CT and CS, and, most importantly, how to integrate CT and CS into content area teaching (Yadav, Stephenson, et al., 2017). Hence, a need exists to better prepare and educate in-service and preservice teachers with regard to CT/CS so that they can more cohesively integrate these within core content instruction for K–12 students (Yadav, Stephenson, et al., 2017). To teach CT/CS within content area learning, teachers need to have not only content knowledge regarding CT/CS but also pedagogical content knowledge regarding the targeted subject domain (e.g., mathematics or science; Shulman, 1986; Yadav et al., 2014; Yadav, Stephenson, et al., 2017). One way to achieve this is through embedding CT/CS experiences in teacher preparation, in particular within content area methods courses to allow preservice teachers to gain experience in integrating CT/CS within subject areas (Yadav, Gretter, et al., 2017).

Preservice Preparation

In a systematic review of research involving the preparation of preservice elementary teachers to teach CT/CS (e.g., coding or robotics), Mason and Rich (2019) found the existing literature to be positive in terms of preservice teachers' content knowledge increasing. Some of the studies in this review also demonstrated increased pedagogical knowledge (i.e., knowledge on how to teach CT/CS) after exposure to CT/CS. Furthermore, existing research indicated exposing preservice elementary teachers to CT/CS resulted in shifts in attitudes toward CT/CS (Cetin, 2016; Yadav et al., 2014). Of the existing literature identified by Mason and Rich (2019)—while studies were split with regard to addressing CT/CS in stand-alone compared with integrated (e.g., educational technology, science methods) courses—however—none were focused on preservice mathematics courses.

Yet, researchers suggest mathematics education as an appropriate content area in which to integrate CT/CS (Gadanidis, 2017; Pérez, 2018). In a study of elementary teachers integrating CT into mathematics and science teaching, the teachers made more connections of CT to mathematics than science (Rich et al., 2019). The researchers found the results support mathematics as an accessible ground in which to integrate CT for students—particularly elementary students. Math, however, is also more often taught in elementary education than science (Curran & Kitchin, 2019). In a review of CT and mathematics, Hickmott et al. (2018) found when CT concepts were discussed in the context of mathematics, the two most common mathematics domains were numbers and operations and algebra. They also suggested a need for more empirical research regarding CT and mathematics for students.

CT and CS and Students With Disabilities

Although limited, a few researchers have focused on CT/CS for students with disabilities. Israel et al. (2018) examined ways to support students with disabilities in learning CT/CS, suggesting teachers use explicit instruction and immediate feedback during instruction. The use of explicit instruction to teach K–8 students with disabilities CT/CS was also supported by Ray et al. (2018). In researching how to directly engage students with disabilities in CT/CS opportunities, Taylor (2018) and Taylor et al. (2017) taught young children with intellectual disability to code a robot to navigate a maze. Knight, Wright, and DeFreese (2019) and Knight, Wright, Wilson, and Hooper (2019) also successfully taught elementary and high school students with autism to code robots. Overall, however, the research regarding students with disabilities accessing and participating in CT/CS is lacking and in need of greater attention.

Despite the increased attention to CT/CS in K–12 education and in teacher preparation, few researchers have examined either CT/CS for K–12 students with disabilities or the preparation of special education preservice teachers to implement CT/CS for students with disabilities. And yet, federal education laws support equal opportunities for all students, including students with disabilities (i.e., Every Student Succeeds Act and Individuals with Disabilities Education Act; Mason-Williams et al., 2020). To provide students with disabilities equal opportunities to CT/CS content—content that supports 21st-century skills (Nouri et al., 2020)—preservice special education teachers need exposure and instruction on CT/CS.

In this mixed-methods study, researchers explored exposing special education preservice teachers to the ideas of CT/CS in the context of a mathematics methods course for students with disabilities or those at risk. The researchers sought to explore the impact of CT/CS exposure on the integration of such concepts into mathematics lesson plans developed by the special education preservice teachers for students with disabilities or those at risk. They further examined the perceptions of the preservice teachers of CT/CS for students with disabilities through lesson plan reflections. Throughout the study in which preservice special education teachers were provided limited exposure to CT/CS principles in the context of mathematics and educating students with disabilities, the researchers sought to answer the following research questions:

> **Research Question 1:** Do special education preservice teachers demonstrate an understanding of CT/CS through appropriate inclusion in lesson plans?
>
> **Research Question 2:** Do special education preservice teachers demonstrate implementation of mathematics concepts and/or the integration of mathematics and CT/CS within lesson plans?
>
> **Research Question 3:** What are the perceptions expressed by special education preservice teachers regarding the value of CT/CS for students with disabilities?

Method

Participants

Thirty-one preservice teachers participated in the research project. Each was finishing their internship year (i.e., student teaching) in preparation to become special education teachers. Of the 31 participants, 30 were female and one was male, a typical representation in the field of special education in general and this particular teacher preparation specifically (National Center for Education Statistics, 2011–2012). All 31 were traditional college students in terms of age (e.g., 21–22 years of age). Twenty-nine of the participants were White; one was Asian and one multiracial. At the university where the study occurred, students wishing to obtain a degree and licensure take 4 years to earn an undergraduate degree, with a focus on special education and elementary education. The preservice teachers then return for a fifth year, which involves a year-long internship, or student teaching, as well as participate in four content courses throughout the year (i.e., two per semester).

The 31 participants represented 86.1% of the special education preservice teachers in the class for the 2019–2020 academic year. Five preservice special education teachers (13.9%) did not participate as they attended the course remotely—due to their internship in another state—and failed to return consent forms. Of the 31 preservice special education teachers, 23 were in special education settings for the spring semester—the semester of data collection—and eight in general education elementary settings. Within the 23 in special education settings, 19 were in elementary schools, four in middle schools, and zero in high schools.

Setting

The study occurred in a preservice special education teacher course in mathematical methods for students with disabilities or those who receive mathematical services within Tiers 2 or 3 in a response to intervention (RtI) system. The university was a midwestern research university, located in a college town next to the state capital. Typically, the content focused on evidence-based or research-based interventions to support students with disabilities or those at risk in mathematics (e.g., the concrete–representational–abstract instructional sequence, explicit instruction, cognitive problem-solving strategies), as well as assessments to guide instruction (e.g., KeyMath), accommodations, and mathematical support for students with more low-incidence disabilities (e.g., functional, early numeracy). The special education preservice teachers taught in urban, rural, and suburban schools in the lower central region of the midwestern state, except for the five who did not participate and were in another state.

The course was taught by a faculty in the special education program whose research focused on mathematics education and intervention for students with disabilities. The instructor was also a co-principal investigator (PI) on a National Science Foundation funded grant involving the integration of CT/CS to diverse elementary students. The course met weekly on Friday mornings for about 2.5 hours across the Spring semester (Spring 2020) in a classroom within the university. The preservice special education teachers sat in self-selected groups within the classroom; five preservice teachers, who were in a different location, participated in the class via Zoom projected at the back of the room. When the class moved completely online due to the COVID-19 pandemic, which occurred during Week 10 of the semester, all preservice teachers attended via Zoom from where they were sheltering at home.

Procedures

During three of the weekly 15 course meetings throughout the semester (i.e., one fifth of the class), the focus of the session was on CT/CS. During these three sessions, the class was led by one or two guest instructors. One of the guest instructors was a faculty member in the educational technology program within the College of Education and PI on the grant; his work focused on CS and CT integration into K–12 education. The other was a doctoral candidate in the educational technology program who previously taught CS at the secondary level. During the three sessions—two face-to-face during the semester and one online due to the COVID-19 pandemic—the two guest instructors provided instruction and support for the preservice teachers relative to CT/CS.

During the first of the three sessions on CT/CS, the doctoral candidate taught the preservice teachers about CT/CS face-to-face. He first presented the major CT concepts of abstraction, algorithm, debugging, decomposition, and patterns. During this lesson, the preservice teachers engaged in unplugged—nontechnology or low-technology—lessons involving CT relative to mathematics, as well as discussions of how to take the sample hands-on activities they tried and translate them for elementary and secondary students with disabilities. For example, one activity the preservice special education teachers engaged in was a network sort performed in parallel. Each number to be sorted using the algorithm involved different number representations (e.g., Arabic, as base 10 blocks, written in English, and in ten-frames). To proceed with the sort, preservice teachers first needed to convert the numbers into a common format. This activity was derived from the CS unplugged curriculum developed by Bell et al. (1998) and then modified so preservice teachers could address issues of place value and alternate representations of numbers in addition to the comparisons and subsequent rearranging of elements. A second activity involved sorting cards with visual representations of shapes divided into sections used to represent fractions of a whole. The objective of this activity was to identify the patterns in similar shapes so as to see how identical fractions looked given different representations. The original activity was modified to include more explicit instruction surrounding the use of the CT vocabulary in defining an algorithm for organizing the cards, decomposition of the steps into subtasks, and the identification of patterns by looking for similar fractional components.

For the second session on CT/CS, the preservice teachers received instruction about plugged CT/CS activities face-to-face from both guest lecturers. For this class session, the preservice teachers were exposed to plugged CT/CS options using the Scratch coding tool. During the class period, the preservice teachers used Scratch in the manner advocated for by Seymour Papert (1980); the preservice special education teachers explored regular polygons using the Scratch sprite as a drawing tool and drew out shapes based on the commands given by the Scratch programmer. For this activity, the angle measures are "discovered" through a process of guess-and-check and debugging based on feedback from the Scratch program. We also demonstrated how preservice teachers could use codable robots like Dash and Dot to bring CT/CS in the context of mathematics instruction. Following the interactive use of these plugged tools, the guest instructors engaged the preservice teachers in conversations about taking these activities and implementing them in K–12 education for students.

The final session regarding CT/CS occurred via Zoom. During this session, the course instructor, two guest instructors, and the two course TAs engaged the preservice teachers in a small-group co-design lesson planning exercise to brainstorm ideas for integrating CT/CS into mathematics instruction or support within their specific settings. Using the breakout rooms via Zoom, each of the authors met with six to seven preservice teachers and engaged in discussions why the preservice teachers individually and jointly completed an interactive Google presentation. The preservice teachers were first asked to think about—and write their individual thoughts and responses into the presentation—their students' needs, learning goals for their students, and how CT/CS could help students learn mathematical ideas. They then brainstormed the activities students typically engage in during a mathematics lesson and what CT/CS practices could then support those activities. Finally, the preservice teachers generated lesson ideas for mathematics that could support CT/CS integration. From their list of ideas, each preservice teacher selected one to develop individually. These ideas were organized on individual presentation slides. After the small-group breakout time, the class reconnected. All preservice teachers had access to the entire Google presentation, although they only engaged with their small group in real time. Note that the content and the structure—aside from being virtual—did not change for the last session, which was conducted during the time of the global pandemic. Each virtual small group had a facilitator, and researchers did not alternate the plan for Session 3 to account for the pandemic, aside from conducting the class on Zoom.

Theoretical Orientation

The work with the preservice teachers was based on the researchers' and instructors' theoretical orientation to Mishra and Koehler's (2006) general Technological Pedagogical Content Knowledge (TPACK) theory as well as the specific argument of the field of CT teacher preparation that teachers should develop an understanding of CT within specific subject matters to gain concrete understanding (Mouza et al., 2017; Yadav et al., 2014; Yadav, Stephenson, et al., 2017). Hence, in this study, the researchers exposed preservice special education teachers to content regarding CT/CS as well as a specific focus on specific pedagogical approaches to integrate CT/CS into mathematics teaching.

Data Collection

Through this mixed-methods research project, researchers collected preservice teachers' lesson plans and reflections. For the course, the preservice special education teachers were required to create a lesson plan in which they integrated CT/CS into mathematics when targeting students with disabilities or those at risk of a disability (i.e., served within an RtI Tier 2 or 3 environment). The lessons could be designed for an individual student, small group, or whole class as the interns were in both general education and special education settings. Furthermore, the lessons could target whatever grade level in which the preservice teachers completed their internship: elementary or secondary. Originally, the preservice teachers were to implement the lesson plans and reflect on their implementation. Given the global COVID-19 pandemic, which resulted in the university moving to online instruction and schools within the state canceling schools for 4 weeks and then moving remote only at the end of the university academic semester, however, the preservice teachers did not deliver their lessons. The preservice teachers, however, were still required to produce a written reflection on the process and their perspectives of teaching CT/CS to students with disabilities within the context of mathematics.

Data Analysis

To analyze the lesson plans, researchers created a rubric. The rubric consisted of 11 items, each on a scale from 0 (*none*) to 3 (*exemplary*; 1 was denoted as *developing* and 2 as *acceptable*). The following 11 items were analyzed across each lesson plan: (a) implementation of one main CT concept (e.g., abstraction, decomposition); (b) implementation of additional CT concepts; (c) use of CT vocabulary within the lesson; (d) accuracy of CT content; (e) integration of computationally rich tools (e.g., robots, computer programming); (f) use of CS as a motivational component of the lesson; (g) assessment of CT concepts; (h) lesson creativity (i.e., lesson plan reflected activities or ideas not presented in the preservice teacher's course); (i) implementation of mathematics concept; (j) integration of math and CT; and (k) implementation of lesson plan (i.e., an assessment of quality, as if someone could implement it as it was written; see Table 1 for the rubric). Each scale rating had descriptive text that was used to generalize the types of factors that would correspond with that rating. The original rubric was designed to include items reflecting integration of math and CT/CS in the context of special education loosely based on prior work on integrated curricula (Berlin & White, 1994). The main categories were then augmented to reflect the desired outcomes of the research team. Using a subset of the teacher lesson plans, the rubric was iteratively tested to determine the reliability of the instrument. This process resulted in the clarification of the descriptive text and adjustment of several of the categories to better align with the research questions. After researchers refined the instrument, they then analyzed the lesson plans in each category using the rubric.

For each element of the rubric, two members of the research team coded at least 25% of lesson plans. Researchers then analyzed interrater reliability (IRR) based on percentage agreement and the Cohen's kappa statistic. The IRR for the CT-based elements (Items a–h) was 75% and kappa was 0.62; the IRR for the math implement, math, and CT integration, and lesson plan implementation was 82.2% and kappa was 0.76. Given the lower IRR for the CT-based elements, additional lesson plans were coded, resulting in a final IRR for those elements of 79.2% and final kappa was 0.71. After IRR was established, the remaining lesson plans were coded independently by two members of the research team. Researchers then examined the codes across the 11 areas for measures of central tendency and spread using mean scores and standard deviation as well as frequency distributions.

For the reflections, researchers used qualitative thematic analysis (Braun & Clarke, 2006). The research team read and reread the reflections to capture the key ideas relative to the research questions. Using an inductive process, the research team familiarized themselves with the data during multiple readings, developed initial codes, and then condensed and collapsed those to generate themes (Braun & Clarke, 2006). After meeting to discuss the themes relative to a small portion of the reflections for training, two members of the research team coded the remaining reflections. Each reflection could be coded with more than one theme, as the reflections—generally two pages in length—were coded by individual

Table 1. Lesson Plan Rubric, With Mean and Frequencies.

Criteria *M* (*SD*)	0 (*None*)	1 (*Developing*)	2 (*Acceptable*)	3 (*Exemplary*)
Implementation of main CT concept $\mu = 1.65$ (0.75)	No CT concept in lesson description Frequency: 2	Limited use of CT concept, or poor connection of concept to student activity Frequency: 10	Reasonable use of CT concept in the context of special education mathematics instruction Frequency: 16	Innovative use of CT concept in the context of special education mathematics instruction Frequency: 3
Implementation of additional CT concepts $\mu = 0.68$ (0.75)	Does not have more than one CT concept in lesson description Frequency: 15	Includes multiple CT concepts but in a cursory way Frequency: 11	Includes multiple CT concepts and uses them in a reasonable manner Frequency: 5	Innovative use of multiple CT concepts in the context of special education mathematics instruction Frequency: 0
Use of CT vocabulary in lesson $\mu = 1.42$ (0.99)	Does not use CT vocabulary in lesson Frequency: 7	CT vocabulary appears in lesson (unclear whether it is introduced to students) or uses it in an incorrect manner Frequency: 8	CT vocabulary appears in lesson and introduces CT vocabulary to students. Use terms to adequately enhance instruction Frequency: 12	CT vocabulary appears in lesson and introduces CT vocabulary to students and focuses on teaching the CT and problem-solving concepts associated with them in a way that improves the lesson Frequency: 4
Accuracy of CT or computing content $\mu = 1.19$ (0.95)	CT or computing concepts are used incorrectly, or they make no attempt to connect to computing Frequency: 9	CT or computing concepts are used in a vague manner that shows limited understanding Frequency: 9	CT or computing concepts are used adequately within the lesson Frequency: 11	CT or computing concepts are well described and connected to both their role in computer science and within the lesson Frequency: 2
Integration of computationally rich tools $\mu = 0.29$ (0.78)	No computationally rich tools are used Frequency: 27	Computationally rich tools are used, but lack connection to math content Frequency: 0	Computationally rich tools are used and make some connections to math instruction Frequency: 3	Computationally rich tools are used and make explicit and strong connections to math instruction Frequency: 1

(*continued*)

Table 1. (continued)

Criteria *M* (*SD*)	0 (*None*)	1 (*Developing*)	2 (*Acceptable*)	3 (*Exemplary*)
Use of computing as motivational component of lesson $\mu = 0.74$ (0.93)	Does not use computer science content to motivate learning Frequency: 17	Uses generic associations to computing (e.g., video games, phones) to motivate learning Frequency: 6	Uses specific connection of CT concepts to real world contexts to motivate student learning Frequency: 7	Connects CT and math to age-appropriate student interests to motivate student learning Frequency: 1
Assessment of CT concepts $\mu = 0.94$ (0.68)	Does not assess CT concepts Frequency: 8	Has limited assessment or student reflection for CT concepts Frequency: 17	Has adequate assessment or student reflection for CT concepts Frequency: 6	Has assessment that connects CT concept to problem-solving or mathematics instruction Frequency: 0
Lesson creativity $\mu = 1.39$ (0.88)	Lesson is derivative of existing ideas shown in the course Frequency: 5	Lesson has some modification to an existing activity that motivates effectiveness of instruction Frequency: 12	Lesson is unique and shows an understanding of CT concepts Frequency: 11	Lesson is extremely innovative, leveraging CT ideas to enhance math instruction in a creative manner Frequency: 3
Implementation of math concept $\mu = 0.87$ (0.72)	No math concepts in lesson description Frequency: 10	Limited use of math concepts or math concepts focus on procedures Frequency: 15	The mathematics concepts focus on developing student conceptual understanding Frequency: 6	The presentation of the mathematics focuses on developing student conceptual understanding and does it in a manner that engages students to think more deeply about the mathematics Frequency: 0
Integration of math and CT $\mu = 0.74$ (0.63)	No integration of math and CT concepts. The focus is on CT or math Frequency: 11	There is a bit of CT in reference to math, but it is not used to teach the targeted math concepts Frequency: 17	CT is used in an adequate way to teach or support the targeted mathematics concept Frequency: 3	CT clearly enhances the mathematics instruction by complimenting the math or problem-solving concepts in the lesson design Frequency: 0
Quality of lesson plan $\mu = 1.23$ (0.62)	One is generally lost with regard to implementation of the lesson plan with the intended audience Frequency: 3	One would need to expand or adapt the lesson plan to implement with the intended audience Frequency: 18	One could implement this with the intended audience Frequency: 10	One could easily implement it with the intended audience; it is well written and clearly conveys what a teacher is doing with CT and math Frequency: 0

Note. CT = computational thinking.

sections, sentences, or expressions. Working on a section-by-section basis, the IRR for coding was 100%. Researchers conducted measures of central tendency for the themes and developed analytical vignettes to highlight the themes across reflections.

Results

Lesson Plans

A range of activities permeated the lesson plans submitted by preservice teachers to integrate CT/CS and mathematics for students with disabilities. The lesson plans included—but were not limited to—ideas about mazes, anchor charts, graph paper programming, decomposition, number lines, and binary bracelets. A few of the lesson plans were original lessons, but many were similar to and were adapted from ideas that were shared with preservice teachers during the course sessions by the guest lecturers. This is reflected in the measure of creativity, for which teachers had a mean of 1.39 (SD = 0.88), which rates on the lower half of the scale between developing (1) and acceptable (3). In addition, the majority of the lesson plans did not involve computationally rich tools, such as Scratch programming or codable robots, which is reflected by the mean for this rubric item (M = 0.29, SD = 0.78), with a mode of 0 (refer to table 1). Across the 31 lessons, only one was coded as exemplary and three were coded as acceptable for use of computationally rich tools.

On average, across the 31 lessons, the preservice teachers were better at highlighting the CT within the lesson than the mathematics, which was oftentimes limited to procedural implementation (i.e., a focus on procedures in mathematics rather than developing conceptual understanding). The average for inclusion of one main CT component was 1.65 (SD = 0.75; mode = 2), whereas the average for the implementation of a math concept was 0.87 (SD = 0.72; mode = 1). In other words, the preservice teachers, on average, were between developing (limited use of CT concept or poor connection of concept to student activity) and acceptable (reasonable use of CT concept in the context of special education mathematics instruction) for use of a main CT concept, but between none (no math concepts in lesson description) and developing (limited use of math concepts or math concepts focus on procedures) with regard to mathematics. The expectation of the lesson design was to highlight the mathematics content using CT/CS ideas, particularly with regard to the pedagogy. The implementation of CT/CS in the lesson plans was promising, however; few preservice teachers involved more than one CT concept (μ = 0.68 [SD = 0.75], mode = 0).

One element that was of particular interest was the degree to which the preservice teachers felt comfortable using the CT vocabulary, both in terms of how the words were defined for the students and how they appeared in the lesson plans to enhance instruction. The preservice teachers were largely successful in this aspect (μ = 1.42 [SD = 0.99], mode = 2). Seven of the 31 used no CT vocabulary (e.g., debugging, abstraction) in their lessons, although some of these lessons included the ideas implicitly. When vocabulary was used, the most common term was algorithm (N = 18), followed by debugging (N = 12) and decomposition (N = 12). The average for accuracy with regard to CT/CS concepts was slightly lower than that of CT vocabulary use (μ = 1.19 [SD = 0.95], mode = 2). For this element of the rubric, the teachers were being evaluated on the accuracy of use of the CT terms or the accuracy of the discussion of computing concepts that were included in the lessons for the purpose of situating the use of these ideas alongside mathematics during instruction. Eight participants demonstrated no accuracy with regard to CT/CS content (i.e., used incorrectly or made no attempt to connect to computing) and two preservice teachers were deemed to be exemplary (i.e., CT or computing concepts are well described and connected to their role within CS and the lesson). In addition to content, the rubric was also used to evaluate the assessment of CT concepts (μ = 0.94 [SD = 0.68], mode = 1). Assessment was considered to be any structured use of reflection, partner, or group work during which the teachers could use informal assessment, or techniques such as exit tickets where the teachers could assess the understanding of the CT idea.

In terms of the integration of CT and math within the lesson plan, the average was 0.74 (*SD* = 0.63, mode = 1). There were no lesson plans that were coded as exemplary and 11 were rated as zero. The average ease of implementation was 1.23 (*SD* = 0.62, mode = 2), suggesting preservice teachers' lesson plans were evaluated as being between one that someone would need to expand or adapt to implement with the intended audience and one that someone could implement as is with the intended audience. There were no lessons that exhibited exemplary quality and three were coded as zero. When the 11 possible categories of coding were summed (maximum = 33), the range for scores across the 31 participants was 1 to 21 (μ = 11.13 [*SD* = 4.72], mode = 11; see Table 2 for summary of lesson plans at minimum total, maximum total, and mode).

While the main focus of the evaluation with the rubric was on the usage of CT ideas and the integration of math content, the evaluators also examined the use of CS to motivate instruction and the ways in which the preservice teachers expanded on the sample activities from the instruction within the methods course. The average across the 31 lessons was below developing for use of computing as a motivation component of the lesson (μ = 0.74 [*SD* = 0.93], mode = 0), but between developing and acceptable for lesson creativity (μ = 1.39 [*SD* = 0.88], mode = 1). Only two preservice teachers' lesson were coded as exemplary for creativity, suggesting the teachers were still formulating their own conceptions of CT/CS and were not engaging in deeper thinking about how to implement these ideas in their mathematics instruction. In both of these cases, the teachers attempted to implement lessons that were not derivative of those presented to the preservice teachers in class.

Reflection Themes

Three main themes emerged from the lesson plan reflections: implementing CT/CS in special education, preservice teacher understanding and confidence, and preservice teacher value for CT/CS. Implementing CT/CS in special education reflects preservice special education teacher articulations of how using CT/CS would impact their pedagogy and lesson design for students with disabilities in mathematics. In other words, it reflects how the preservice teachers noted ways they would teach CT/CS to students with disabilities, including adjustments. Preservice teacher understanding and confidence captured the special education preservice teachers' statements about their knowledge of CT/CS and beliefs they could teach the CT/CS ideas successfully. This theme captured the teachers' expressions of CT/CS knowledge and their feelings of confidence for implementation. The preservice teacher value for CT/CS theme emerged from statements regarding the features of CT/CS teachers felt would enhance or hinder the lessons they had designed for the students in their placements. In addition, the theme reflected preservice teachers' opinions on the importance of CT/CS content for students with disabilities. Of the 92 separate sections coded across the 31 reflections, 41.3% of the codes reflected implementing CT/CS in special education, 41.3% preservice teacher value for CT/CS, and 17.4% for preservice teacher understanding and confidence.

Implementing CT in special education. The theme of implementing CT/CS in special education reflected the preservice special education teachers' perspectives on how to implement CT/CS with students with disabilities. This included those who reflected on the selection of technology or the selection of particular CT vocabulary to highlight. It also captured the sentiments of preservice teachers who reflected on the pedagogical approaches for teaching CT/CS for students with disabilities (e.g., one-on-one, explicit instruction), although not explicitly with regard to contrasting if they were implementing the same or similar lesson for students without disabilities. With regard to technology, two perspectives were represented—one suggesting a need to start with unplugged and the other to start with plugged technology. For example, one preservice teacher reflected,

Table 2. Examples of CT/CS and Math Lesson Plan Coding.

Criteria	Lesson 1 (mode 11)	Lesson 11 (mode 11)	Lesson 18 (max 21)	Lesson 34 (5)
CT or CS	CT (no technology)	CS—Scratch Jr. app on iPad	CT (tech, but not related to CS)	CT (no technology)
CT vocabulary	Algorithm	—	Algorithms, debugging	—
CT concepts	Algorithm	—	Algorithms	Binary numbers
Math concepts	—	—	Telling time	—
Summary of activity in lesson plan	Write directions to follow a maze	Moving a Scratch character to targeted places around the screen	Showing or representing time on virtual clock	Making a binary number name bracelet
Coded rubric				
Main CT implementation	2	2	2	2
Additional CT implementation	0	0	1	0
CT vocabulary	2	0	2	0
Accuracy of CT/CS content	1	2	2	0
Computational-rich tools	0	2	2	0
Computing as motivation	1	2	1	1
Assessment of CT	2	0	2	1
Creativity of CT/CS	1	2	3	0
Math implementation	0	0	1	0
Integration of math & CT	0	0	2	0
Lesson plan quality/implementation	2	1	2	1
Total	11	11	21	5

Note. CT = computational thinking; CS = computer science.

> I would start with no technology and work my students up to actually using technology. I think making Computational Thinking and algorithms simpler for them, such as a describing them as a set of directions, would make the concept less abstract.

In contrast, another preservice special education teacher shared,

> I definitely think that incorporating coding and technology into math and school in general with students that have disabilities could work, I just know that each step would need to be explicitly taught and really broken down [decomposition] for them.

This preservice teacher also noted a pedagogical approach to teach CT/CS to students with disabilities specifically, such as explicit instruction, which was emphasized by multiple preservice teachers (e.g., "Because of [the challenges of introducing CT and CS] I need to make sure I give explicit instructions to help them better understand the lesson"). Other preservice teachers noted the use of CT skills—and vocabulary—such as decomposition and pattern recognition could help students struggling with place value and fractions. Many referenced using anchor charts to highlight vocabulary and simultaneously demonstrating the process, such as decomposition.

Preservice teacher understanding and confidence of CT/CS. The theme of preservice teacher understanding and confidence reflected teacher concerns about implementing CT/CS as well as their confidence to do so. In other words, this theme captured how preservice special education teachers explicitly or implicitly noted the limitations of preservice teachers to use CT/CS for students with disabilities. Across the responses, diverse views were represented. A small number of preservice special education teachers noted they were not confident in their ability to teach CT/CS. This was encapsulated by a respondent who reflected, "I think I need to learn the activities better myself before I teach the students, but I think the students with disabilities will love to do the activities." A consistent pattern found across respondents with regard to confidence was that it grew as a result of the instruction they were provided during the course relative to the study (e.g., "While I have not had much experience with computer science and computational thinking before this, the opportunities that we have had completing different activities during class have helped me develop a better understanding. After learning more about it, it can be related to math in so many ways and I think it can be very beneficial for students to engage in CT/CS activities"). Some of the preservice teachers viewed their lack of experience with computing as an advantage when planning their CT/CS lessons, expressing they were able to easily identify areas of confusion, as they had been confused about these same ideas themselves when learning about CT/CS.

In addition to confidence in their ability to teach these concepts to students with disabilities, preservice teachers reflected on their own understanding of CT/CS concepts. Some explicitly stated special education teachers' limited understanding of the content (e.g., I also would be concerned that teachers do not know enough about the topic to feel comfortable teaching the subject. If a teacher does have the knowledge, it might be easier for them to figure out how to make it fit into the classroom. For teachers, including myself, who are less knowledgeable in this area, it can be daunting to try to figure out what to teach and also how to teach it"), whereas some showed their limited knowledge through statements made in the reflections. In other words, in their reflections some preservice special education teachers demonstrated a lack of understanding of CT/CS through their statements, which were deemed inaccurate with regard to CT/CS. For example, one preservice teacher wrote, "The first step was Abstraction, I used this term with reading the directions, because so many students forget to do this important part. After that we went into Algorithms because these are the equations that they are solving." The term *abstraction* is used most often to look for general patterns across similar items and form a simplistic model of those items, ignoring unnecessary detail. It was unclear to the researchers through this statement how the preservice teacher intended the students to use abstraction with regard to the directions they were giving.

Preservice teacher value for CT. The third theme that emerged from the work reflected the positive sentiment of CT/CS implementation expressed by many of the preservice special education teachers; dissenting opinions, however, also existed. Many of the preservice teachers stated how CT/CS instruction would provide advantages for their students with disabilities, pointing to specific concepts they thought would be beneficial (e.g., "I think that there are . . . skills that students with disabilities can benefit from, such as creativity and higher thinking skills. These are important for students with disabilities, as they grow as learners. By providing experience with these skills, it might also open the possibility for the students who enjoy working with computers to get more experience" and "I wanted to embed them [the CT terms taught to the preservice teachers] into the lesson because . . . these skills can be used in the students everyday mathematic and life skills as well").

Other preservice teachers expressed that while they noted the importance of CT/CS, they were not sure whether students with disabilities specifically would benefit from or be able to complete the activities (e.g., "While I saw the benefits from doing these activities, would my students feel the same way? For my students with special needs, I am not confident that these activities would benefit their learning process like it did with mine"). These preservice teachers pointed to the added complexity of introducing computing concepts to lessons that the students were already struggling with in mathematics. One teacher questioned teaching CT/CS to students with disabilities outright, stating they "struggled to see the real benefit of using computational thinking or computer science in schools." Others noted the heavy demands consistently placed on special education teachers' instructional time:

> I also feel that teachers are already asked to cover so much in their school days. They already have to pick between science and social studies to decide which subject they want to cover and when they will squeeze it in. There just is not enough time in the day.

Discussion

In this study, researchers explored exposing special education preservice teachers to the ideas of CT/CS in the context of a mathematics methods course for students with disabilities or those at risk of disability. Researchers analyzed lesson plans designed to integrate CT/CS into mathematics for these students and preservice special education teacher reflections of those lesson plans. Overall, the results show emerging promise with regard to limited exposure of preservice special education teachers to ideas of CT/CS as it translates into developing lesson plans for students with disabilities in mathematics. The results, however, also suggest that future teachers need additional exposure to computing ideas and more experience with integrating CT/CS for mathematics.

Overall, few lessons analyzed using the rubric were exemplary; that is not, however, altogether surprising given (a) the lessons were constructed in a global pandemic, resulting in the move of K–12 schools—and higher education—to emergency remote learning and thus the preservice teachers were aware that their lesson plans would not be implemented and (b) the three sessions represented initial exposure of the ideas of CT/CS for the majority of the preservice teachers. As noted, prior to the planned third lesson on CT/CS for the preservice teachers, both K–12 schools and institutions of higher education in the state moved to emergency remote learning. The preservice teachers were aware that they would be unlikely to implement their lesson plans as some schools provided no instruction and other schools just reviewed previously learned material with their students (i.e., attendance was not taken during emergency remote learning and no grades were given) for students with and without disabilities. The lack of implementation likely affected the preservice teachers lesson plan quality. Furthermore, the fact that preservice teachers too were experiencing a global pandemic in which they were quarantining and sometimes isolated may have negatively impacted their motivation and quality of work. The researchers plan to replicate this study during more typical conditions to determine the efficacy of small exposure to CT/CS when considering students with disabilities. They also plan to examine the issues longitudinally. For example, the researchers plan to implement general instruction (i.e., not mathematics specific) on CT/CS ideas into an undergraduate course that preservice special education teachers take their senior year and then to continue to implement mathematics special CT/CS instruction during the same preservice teachers' internship a year later to examine the impact on lesson quality and reflection.

In terms of the reflections, the majority of preservice special education teachers were positive toward integrating CT/CS in mathematics for students with disabilities, even if they were not always completely confident in their ability to do so, felt they had access to the range of tools to do so, or felt they had sufficient knowledge on CT/CS. A few preservice teachers, however, questioned the value of CT/CS for students with disabilities. This is not surprising given research suggesting special education teachers are already asked to do so in terms of roles and responsibilities, which many contribute to being one of the reasons special education teachers leave the field (Hagaman & Casey, 2018). The reflections further highlight the mix of feelings preservice teachers may feel regarding CT/CS based on their confidence level and general understanding of computing ideas (Bell et al., 2016; Cateté et al., 2018).

Implications for Practice

In terms of implications for practice, the researchers suggest the need to prepare preservice special education teachers and preservice general education teachers to teach CT/CS to students with disabilities and to increase their awareness of why these ideas are important for students in this population. While the majority of preservice special education teachers expressed the importance of students with disabilities gaining access to CT/CS, there were some who felt special education teachers already do too much or that CT/CS implementation might detract from the needed focus on areas of struggles. This suggests preservice special education teachers need to be better prepared to recognize how CT/CS can fundamentally support Individualized Education Program (IEP) goals for students with disabilities instead of being an add-on. It further suggests the need to ensure general education preservice teachers truly know how to support CT/CS for *all* students, such as utilizing Universal Design for Learning (UDL) and recognizing accommodations that may need to be made. Another implication is the need to expose preservice teachers to CT/CS more than once (i.e., one class) during their teacher preparation programs. Although the exposure to CT/CS was beneficial, there was still more learning and deep thinking needed by the preservice teachers regarding CT/CS for students with disabilities and those at-risk. Furthermore, during exposures to CT/CS, those providing the CT/CS content should make concerted efforts to connect this content to the research-based and evidence-based practices for educating students with disabilities, such as explicit instruction. For many lesson plans, the attention to CT/CS and its integration with mathematics, was more at a surface level. With additional and deliberate exposure, such as in other preservice special education courses, preservice teachers can gain a deeper understanding of CT/CS and how to implement it for students with disabilities. In addition, overall preservice teachers did not feel confident to implement CT/CS, which suggests that they might need additional support to first learn these ideas and tools themselves as well as how they could be integrated into their instruction. Prior work has suggested that elementary in-service teachers do see connections between CT ideas and their mathematics and to some extent science instruction (Rich et al., 2019). As such, one model might be for in-service and preservice teachers to work together to develop and implement lessons that support CT/CS learning for students with disabilities.

Limitations and Future Directions

The limitations of the study include that it was conducted, unfortunately, during an unanticipated global pandemic that affected the preservice teachers' ability to implement the lesson plans, likely resulting in decreased motivation to construct them. As previously suggested, the researchers plan to replicate the study during more usual conditions in which the lesson plans are implemented with students with disabilities or those at risk of a disability. Another limitation of the study was the inability to achieve 100% participation among course participants. Consent forms for five preservice teachers were not returned; these five were all completing their internship in the same urban school district in another state and typically participated virtually for the class session. They might have brought a unique perspective to the analysis.

Researchers also acknowledge only three sessions being devoted to CT/CS as a limitation. Given the content needed to be covered in the course and the lack of research on this topic, however, using one fifth of the course to focus on CT/CS for students with disabilities with preservice special education teachers is a start. Furthermore, the researchers acknowledge that the method of assessing—lessons plans—may have been problematic given how new the preservice teachers were to the ideas of CT/CS in general, let alone for integration with mathematics. In addition, with the exposure to CT/CS, most likely to be limited, teacher educators need to make the most of their limited time by connecting the ideas of CT/CS with research-based or evidence-based practices and approaches to educating students with disabilities, including—but not limited to—explicit instruction and UDL. Aspects of use of evidence-based or research-based practices for educating students with disabilities (e.g., explicit instruction or UDL) were not assessed in the lesson plan rubric; neither were issues of accessibility or accommodations. While students were directed to design their lesson plan targeting students with disabilities or those at risk, in the future researches may seek to expand the rubric to more holistically evaluate lesson plans for supporting all students. Relatedly, the researchers developed the rubric; in the future, researchers may seek to validate the rubric, in addition to expanding it to be more inclusive (e.g., inclusive of UDL or accommodations). Also, with the reflections, the authors analyzed them via qualitative means; researchers, however, did not acquire triangulation for the results. Finally, the impact on students with disabilities or those at risk was not examined with regard to the CT/CS lesson plans.

For future directions, beyond replication, the researchers also seek to extend the examination of CT/CS preparation for preservice special education teachers on the experiences of students with disabilities and the perceptions of the preservice teachers toward CT/CS implementation and use for students with disabilities. As noted, the researchers plan to implement non-mathematics-specific CT/CS information to undergraduate special education preservice teachers—with attention to UDL—and examine their knowledge and perceptions toward CT/CS and for students with disabilities. The researchers also plan to examine the impact longitudinally of multiple exposures, analyzing the lesson plans and reflections of preservice teachers with respect to mathematics who also received nonmathematics instruction on CT/CS as undergraduates. Researchers should also seek to examine other methods of assessing preservice teachers' knowledge and application to practice. As noted, limited exposure may be insufficient to assess in lessons plans. Researchers should also seek surveys in which content knowledge of CT/CS is ascertained. Finally, the researchers also plan to examine lesson plans and perceptions of in-service teachers engaged in a graduate teacher preparation course with regard to CT/CS. This examination includes analyzing how in-service special education teachers develop and implement lessons—including the use of evidence-based or research-based practices for educating students with disabilities, such as explicit instruction; their perceptions of CT/CS; and a comparison of their perceptions to those of preservice special education teachers.

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ORCID iD

Emily C. Bouck https://orcid.org/0000-0002-0515-7627
Aman Yadav https://orcid.org/0000-0003-4247-2033

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Author Biographies

Emily C. Bouck is a Professor and Director of the Special Education Program at Michigan State University. Her research focuses on RtI for mathematics and mathematics interventions for students with disabilities and those served within a RtI framework. She also teaches the mathematics methods course for students with disabilities.

Phil Sands is a PhD candidate in Educational Psychology and Education Technology (EPET) at Michigan State University, studying computer science education, motivation in computer science, and issues of broadening participation. He recently completed seven years of work in educational outreach for Purdue University in the Department of Computer Science. Previous to that, he spent seven years teaching statistics and computer science to high school students in Michigan and Maryland.

Holly Long is a second year doctoral student in Special Education at Michigan State University. Her research interests involve mathematics interventions for students with extensive support needs as well as teacher implemented mathematics interventions in the classroom.

Dr. Aman Yadav is a Professor of Educational Psychology and Educational Technology at Michigan State University. His areas of expertise include computer science education, problem-based learning, and online learning. His research and teaching focus on improving student experiences and outcomes in computer science and engineering at the K-16 level.