Preservice Teachers Designing Assistive Educational Robots Using Computational Thinking

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This study examined how an online instructional module that included an unplugged robot design activity integrated computational thinking (CT), assistive technology (AT), and universal design principles into a preservice teacher education class. The research focused on how this module shaped understanding, attitudes, and comfort levels about integrating these concepts into their future classrooms. The population of this study consisted of 59 students enrolled in an upper-division online undergraduate instructional technology course over three semesters. The module was developed collaboratively by education and computer science faculty members by infusing activities adapted from an unplugged robot design lesson created for introductory computer science students (Imberman et al., 2017). The module culminated with an assignment in which students used paper and pencil to design a robot that solved an educational problem that a teacher may face in a classroom that also contained features to make it accessible to students with special needs. The module increased knowledge of CT and comfort with teaching the topic in their future classroom. Participants gained knowledge about AT but said they were not comfortable using AT in future classrooms.

Wing (2008) drew attention to the viewpoint that computational thinking (CT) is a fundamental analytical skill that every child should be taught, just as reading, writing, and arithmetic are. Since this assertion, there has been a growing global movement for educational organizations and systems to adopt standards that include CT instruction in K12 schooling. For example, in 2013, the Australian Curriculum, Assessment and Reporting Authority (ACARA, 2016) expanded technology education expectations to include CT, along with the concepts of design thinking, robotics, and programming.

At the global level, the International Society for Technology in Education (ISTE, 2016) expanded the emphasis on CT by updating its standards for students and competencies for educators (ISTE, 2018). While the concept of CT may be common knowledge among the computer science education community, K12 teacher educators are less familiar with what CT entails (Yadav et al., 2017).

To prepare preservice teachers for classrooms that have evolved to include diverse student populations, teacher programs often include curricula incorporating Assistive Technology (AT). In the US, the *Individuals with Disabilities Education Act of 2004* (IDEA) requires schools to make certain that AT devices are provided to each student with special needs. "AT is mandated by law, both general and special education teacher preparation programs in higher education need to establish a mechanism for including AT in their programs of study in order to align with the law, professional standards, and classroom practice" (Poel et al. 2013, p. 29). AT integration goes beyond the classroom to the global level. The Rehabilitation Engineering and Assistive Technology Society of North America (https://www.resna.org) coordinates the development of Assistive Technology Standards in collaboration with international organizations in various conditions, including AT for air travel, sports equipment, and wheelchairs, to name only a few.

A study of 407 teacher education programs by Gronseth et al. (2010) found that students in general teacher education were receiving AT instruction. Still, many reported that more instruction in AT was needed to make students more comfortable using AT in the classroom. A newer study by Jones et al. (2018) discusses how the creation of an AT lab at their university significantly increased student success with the implementation of AT. Another study by Park et al. (2021) found that the combination of an AT and Instructional lab that included demonstration and hands-on experiences was particularly beneficial to general education students to feel better prepared and have a more positive perspective on using AT in their future classrooms. Together both the older and more recent studies indicate the need for AT infusion into the general preservice teacher curriculum.

This article describes an instructional module in a teacher education course that combined CT and AT, where students designed unplugged assistive robots to help with an educational problem. This mixed-methods study took place at a large public university in the US state of Florida. The module was developed collaboratively by education and computer science faculty members by infusing activities adapted from an unplugged robot design lesson created for introductory computer science students (Imberman et al., 2017). The module culminated with an assignment in

which students used paper and pencil to design a robot that solved an educational problem that a teacher may face in a classroom that also contained features to make it accessible to students with special needs. We then examined how this module shaped students' knowledge and attitudes toward the concepts of CT and their perceived comfort in incorporating CT into their future classrooms. Further, we examined how students explained the concepts of CT, AT, and robotics and examined the types of educational problems the students' robot designs solved.

Literature Review

Integrating CT Into Teacher Education Curricula

The nature of CT is interdisciplinary, which can also be a challenging concept for preservice teachers. Colleges of engineering, science, and education often create curriculum to help preservice teachers learn the basic skills to integrate CT and Robotics into their future classrooms. In a literature review on preparing elementary school teachers to teach computing, coding, and CT, Mason and Rich (2019) stated that teacher training for computing is lacking in elementary education.

There are different approaches to integrate CT and Robotics into the preservice curriculum. Adler and Beck (2020) created an introductory computer science course, named Computer Science for All, to help CS students get a strong foundation in the field and foster CT in preservice teachers (CS for ALL, 2019, n.p.).

This mixed-methods study demonstrated that self-efficacy in CT skills increased in all students and that education students also increased their confidence in coding and expressed an intention to incorporate CT projects in their classrooms. The School of Education at Iowa State University offers a course named Toying with Technology to help preservice teachers understand CT (Tank & Culver, 2019). Students are then given several opportunities to practice applying CT through guided tutorials and robotics activities in this course. Finally, "students are asked to apply CT in a more open-ended environment with reduced scaffolding" (p. 337). One of the final projects has student groups plan two CT activities to deliver to kindergarten students at a partner school.

Cheng et al. (2018) investigated preservice teachers' perceptions of CT and their conceptualizations within K12 education. The study participants took part in one of the two-course designs embedded in an initial teacher education program. The first provided a broader overview of ISTE standards, the coding movement, and coding in education. The second included more extensive coverage of the topics plus hands-on experiences in a makerspace setting. The study results indicated that the students who took part in the more expansive course design with the makerspace component responded to reflection questions in a way that demonstrated they were more readily able to conceptualize the use of CT in their future classrooms.

To explore the construct that CT can be applied across different subject areas, Yadav et al. (2016) integrated a CT module into a preservice teacher educational psychology course. Their study found that the students

completing the module had a better grasp of how CT can be integrated into their future teaching by promoting algorithmic thinking, abstraction, and problem-solving (and not by merely using computers). The authors concluded, "In summary, we have shown that given relevant information in CT, preservice teachers' knowledge of CT and ideas about how to incorporate CT in their future classrooms increases." (p. 14)

Few teacher preparation programs in the United States provide opportunities for their students to develop CT skills, and interventions of this nature are emergent, with limited emphasis on developing pedagogical content knowledge (Suters, 2021). The Technological Pedagogical Content Knowledge (or Technology, Pedagogy, and Content Knowledge [TPACK]) model described by Koehler and Mishra (2009) represents an interaction between content, pedagogy, and technology and is commonly used to study technology integration. Course activities from prior studies suggest that including CT in K12 preservice teaching should increase their pedagogical content knowledge (PCK). "PCK covers the core business of teaching, learning, curriculum, assessment and reporting, such as the conditions that promote learning and the links among curriculum, assessment, and pedagogy" (p. 64).

Mouza et al. (2017) used Mishra and Koehler's (2009) TPACK framework in examining how participation in a CT-infused educational technology course influenced preservice teachers' dispositions and knowledge of CT concepts. In addition, they explored ways in which knowledge could be combined with content and pedagogy to achieve meaningful student outcomes. Their results indicated that the curriculum positively influenced participants' knowledge of CT concepts, tools, and practices. However, some participants demonstrated only a superficial understanding of CT and could not design lessons that meaningfully integrated CT tools and concepts with content and pedagogy. These findings highlight the need to integrate CT instruction with coursework in teaching methods across curricula to prepare preservice educators to develop a deeper understanding of teaching CT concepts effectively. "CT can be developed in multiple contexts and within subject areas beyond computer science, frequently without necessitating the use of programming" (p. 63).

Infusing AT Instruction in Teacher Education

The Florida Alliance for Assistive Technology (n.d.) defined AT as any device, gadget, hardware, or software used by a person to do things for themselves that might otherwise be difficult or impossible to do because of their disability. Assistive technology robots are one of the tools starting to be used for AT in classrooms. A literature review on educational robots by Liu et al. (2016) reported 74% of the studies had used robots in the context of STEM education, while 21% of the studies have used robots in language education, and only 4% have employed robots in special education for Autism Spectrum Disorder (ASD).

Alcorn et al. (2019) found that the structured and consistent interactions robots exhibit can be helpful for children with ASD to stay engaged in learning and help them transition to human-to-human interaction. Encarnação et al. (2017) used virtual and physical robots combined with

augmented reality and communication devices with students who displayed motor and speech disabilities for use in inclusive classrooms. They found virtual and physical robots equally allow children with these challenges to participate actively in academic activities. "Teachers considered that the system allowed for adapting activities in their annual curricular planning, without the need for drastically changing what was planned" (Encarnação et al., 2017, p. 116).

Integrating Unplugged Assistive Robot Activities to Help Solve Educational Problems

Many robots can support AT in the classroom. Robots are used for teaching a second language, customizing instruction, encouraging social and emotional skills, and collecting data on student progress.Several types of robots have shown promise with communication in children with developmental delays (Gottsegen, 2020). Plugged-in robotics activities can be engaging but require the use of costly robotics kits. Thus, unplugged activities can be feasible to introduce computer science concepts when funding is not available. Adding an unplugged assistive robot activity into the preservice classroom. Powers and Azhar (2020) adapted a type of unplugged robot activity in preservice and graduate teaching classes and found it easy to integrate CT into the curriculum.

The Present Study

Globally, there has been a growing trend for K12 school systems to integrate CT instruction into K12 classrooms. For example, in the United States, the *Computer Science for All* initiative aimed to provide K12 students with the opportunity "to learn Computer Science (CS) and be equipped with the CT skills they need to be creators in the digital economy, not just consumers, and to be active citizens in our technology-driven world" (CSforALL, 2019, para. 4). The current study addresses this need by implementing CT and AT concepts into teacher preparation curricula.

The purpose of this mixed-methods study was twofold. First, we added an instructional module that integrated AT and CT into instruction to explore how preservice teachers' knowledge and attitudes toward AT and CT might change. Next, this study examined how the students who participated in the instruction explained the concepts of CT, AT, and robotics and the types of educational problems the students' robot designs solved. In doing so, the following research questions were asked:

1. Is there a significant change in the preservice teachers' knowledge and attitudes toward CT and AT?
2. Is there a significant change in the preservice teachers' comfort in using CT and AT in their future classrooms?
3. How do preservice teachers explain the concepts of CT and robotics after participating in the lesson?
4. What kind of educational problems did the robot designs of the preservice teachers address?

An explanatory mixed-methods design, as described by Fraenkel et al. (2012), was utilized to answer the research questions. By following up the quantitative analysis with qualitative inquiry, we were able to gain deeper

insight into the qualitative findings by painting a picture of preservice teachers' knowledge of AT and CT. According to Cheng et al. (2018), "The current state of the art of educational robots indicates an urgent need to explore the essential applications of such robots" (p. 400). This research can help spark CT connecting the educational applications of assistive robots in preservice teachers while exploring innovative methods of teaching these concepts.

Methods

Description of the Instructional Module

The authors of this paper include two instructional technology faculty members who taught the courses examined in this study and a graduate research assistant who also contributed to this project. A computer science professor from another university collaborated in the development of the learning module. All sections of the online course used a standardized syllabus and a Canvas course shell to deliver the instruction. The module in the upper-division instructional technology course was designed to infuse activities adapted from an unplugged robot design lesson created for introductory computer science students (Imberman et al., 2017). When the module was adjusted for preservice teachers, the activity was aligned with the Florida Educator Accomplished Practices (Florida Department of State, n.d.) and the ISTE (2018) Standards for Educators. Students were introduced to the ISTE resources, instructor created presentations, handouts, and booklets. The list of resources to help students with the AT robot project are in Table 1.

Table 1
Resources to Help Students With the AT Robot Project

| |
|---|
| Create a drawing of a robot to help solve the problem that includes accessibility features.

A video created by the University's AT resource center. https://www.fau.edu/sas/ |
| A virtual poster that contains an extensive list of free and low-cost AT resources for teachers and students (Rebar et. al 2019). |
| Robotic Technology, Overview, Types and Uses (Built In, n.d.). |
| Classroom Robots are Infiltrating the Education Industry, but Teachers are Safe-For Now (Gottsegen, 2020). |
| Robotic pets provide a solution for seniors facing isolation (Ryan & WHAM staff, n.d.). |

1. At the conclusion of the module, students were instructed to create a robot drawing with accessibility features to help with an educational problem. Students were provided with a picture of an example robot and asked to take a picture of their robot with their smartphone and turn it in. The example robot given to students in Figure 1 is named "BOT the Helper" and was designed to help with visual challenges. This robot would stand on a student's desk and include a microphone and the ability to enlarge text size. Along

with the robot drawing, students were asked to respond to the following questions that were scored with a rubric/checklist:

2. What problem in education does your robot help solve?
3. What features does your robot need (hardware, software, anything additional) to successfully perform its functions?
4. How does each label/note you have placed on your robot relate to the features it needs?
5. What types of physical obstacles would your robot have to overcome?
6. What types of psychological challenges do people have to overcome to accept your robot service?
7. What features help with certain accessibility challenges?

Figure 1
Bot the Helper: Example of a Student Robot to Help With Visual Challenges
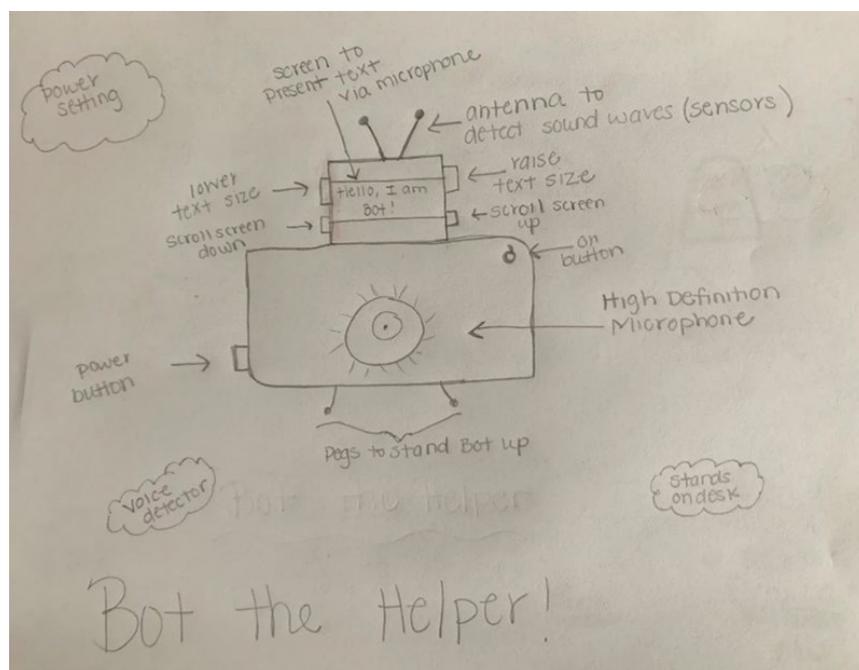
Data Collection

Data for this study were collected using a pre-and posttest survey that was created with Qualtrics software. The survey contained 25 items, although not all of them were used in this analysis. The first question was the optional consent of the student to be included in the study. The next group of items was designed to collect demographic and background information about the participants. The following section included items from the instrument used by Yadav et al. (2017) that were adapted to assess preservice teachers' perceived knowledge and attitudes toward CT in three categories: Definition, Comfort, and Interest. The remainder of the multiple-choice items gathered data about participants' perceived knowledge and attitudes toward AT, as well as their perceptions regarding implementing both CT and AT in their future classrooms. In addition, the

following open-ended survey items were included to gather qualitative data for this study:

1. How would you explain the concept of CT?
2. How would you explain the concept of robotics?
3. What problem in education does your robot help solve?

Another source of data collected was classroom artifacts, which were the participants' drawings of their robot designs and responses to reflection questions.

Participants

Fifty-nine students enrolled in an upper-division undergraduate instructional technology course participated in the study. The course was delivered during summer and fall 2020 and spring 2021 terms via distance learning at a large public university in the southeastern United States. The majority of the students were pursuing a degree in the education field (93.2%), including early childhood, elementary, and exceptional student education, as shown in Table 2. As this was an upper-division course, a few graduate education students were also in the course.

Table 2
Participants by Degree Program

Degree Program	*N*	%
Bachelor in Early Child Care and Education	17	28.
Bachelor of Arts in Education in Exceptional Student Education/ESOL K-12	4	.8
Bachelor in Elementary Education with ESOL and Reading K-6 Endorsement	30	50.8
Bachelors of General Studies (BGS)	2	3.4
Masters Degree in Education	2	3.4
Pursuing a different degree	4	6.8

As is common among education majors, the participants were predominantly female at 86.4% (*N* = 51), seven were male (11.9%), and one participant preferred not to answer the survey item about gender (1.7%). Most students were of the traditional college-age range of 18 to 22 (62.7%), with some students in higher age ranges of 23 to 27 (30.3%), ages 28 to 32 (11.9%), and 30 or greater (5.1%).

Once approval was obtained from the university's institutional review board, the surveys were administered electronically within the instructional technology course via a learning management system. Two of the researchers involved in this study taught the course, but the survey was also included in sections of the course taught by other instructors not involved in this study. Within the course, students were provided with a link to the pretest survey prior to taking the CT and AT instructional module and the post-test survey after the instruction. Although all students were presented with the surveys, participation in the research was voluntary; thus, only students who consented to participate were included in this study.

Data Analysis

Quantitative Analysis

The quantitative data were entered into SPSS® 27 software for analysis. Descriptive statistics were calculated for self-reported demographic and background variables to paint a picture of the study's participants. The survey items regarding knowledge, attitudes and future classroom use of CT and AT were summarized by calculating descriptive statistics. Next, a one-sample paired *t*-test was run on the sample of 59 preservice educators to determine whether there was a statistically significant mean difference between their self-reported ratings of knowledge, attitudes, and future classroom use of CT and AT of participants between the pretest and posttest surveys.

To assess the validity of the paired *t*-test results, the differences in means of the paired values were calculated and plotted on histograms. An examination of the histograms showed the values were roughly bell-shaped, satisfying the assumption that the values must be approximately normally distributed for the one-sample paired *t*-test to be valid.

Finally, we evaluated the effect size of any statistically significant findings by examining the value of Cohen's *d*. According to Walker (2008), when comparing two samples' means, *d* is obtained by calculating the difference in the means divided by the average of their standard deviations. It is also automatically generated when a paired *t*-test is run in SPSS® 27. In assessing effect size, a d of 1 indicates that the means differ by one standard deviation, and a *d* of 0.2 can be considered a small effect size, 0.5 a medium effect size, and 0.8 a large effect size.

Qualitative Analysis

Qualitative methods were used to analyze data gathered from the open-ended survey items and participants' artifacts, namely their robot design assignments. Qualitative analysis seeks to uncover categories, themes, and patterns that appear in qualitative data (Patton, 2014). Once the data were collected, information from the open-ended survey items was organized into tables in electronic word processing software and coded by two researchers, one of whom was not an instructor in the instructional technology course examined.

A list of a priori codes that relate to the research questions posed by this study was utilized as a starting point. Later, the code list was adapted to accommodate unexpected findings. In doing so, additional coding categories were developed by reading over all the data and searching for regularities, patterns, and topics the data covered, and then writing down words and phrases that represented the topics and patterns that were not included in the initial set of codes (as recommended in Bogdan & Biklen, 2007). We then systematically sorted the data into the final set of coding categories. Finally, we examined the categorized data to identify any overarching themes or thematic findings (see also Merriam, 1998).

Mixed-Methods Analysis

An explanatory mixed methods design, as described by Fraenkel et al. (2012), was utilized for this study. In doing so, we first evaluated the quantitative research questions (1 and 2) and then followed up with qualitative analysis (Research Questions 3 and 4) to flesh out and refine the quantitative findings. By following up the quantitative analysis with qualitative inquiry, we gained deeper insight into the qualitative findings by painting a picture of preservice teachers' knowledge of AT and CT through the analysis of open-ended questions and participants' drawings of assistive robot designs.

Results

Quantitative Results

Descriptive Statistics

Descriptive statistics for participants' self-reported ratings of survey items regarding knowledge and attitudes toward CT and AT are summarized in Table 3

Table 3
Descriptive Statistics of Pre- and Posttest Survey Items

Item	Pretest		Posttest	
	Mean	*SD*	Mean	*SD*
CT involves thinking logically to solve problems	6.34	.822	6.41	.726
CT involves abstracting general principles and applying them to other situations	5.88	1.274	6.24	.961
I can learn to understand CT concepts	5.85	1.201	6.05	.826
I do not use CT skills in my daily life	2.98	1.468	3.14	1.732
I think CT is boring	3.68	1.420	3.09	1.582
I think CT is interesting	4.92	1.500	5.21	1.361
How comfortable do you feel about incorporating the concept of CT into your future classroom teaching environment?	5.36	1.310	5.78	.918
How knowledgeable are you about assistive technology?	2.69	.863	3.17	.901
How comfortable do you feel assisting a student using assistive technology?	3.21	.720	3.45	.841
How prepared do you feel about working with someone who requires assistive technology?	2.95	.963	3.21	.874

Knowledge and Attitudes Toward CT and AT

Research Question 1 asked, "Is there a significant change in the preservice teachers' knowledge and attitudes toward CT and AT?" The results of the paired *t*-test for preservice teachers' self-reported ratings of knowledge and attitudes toward CT are presented in Table 4.

Table 4
Results of Paired T-*Test of Knowledge and Attitudes Toward Computational Thinking*

Survey Item	Paired Differences					t	df	Sig. (2-tailed)
	Mean	*SD*	Std. Error Mean	Confidence Interval Lower[a]	Confidence Interval Upper[a]			
Knowledge								
Computational thinking involves thinking logically to solve problems	.034	.878	.115	-.196	.265	.299	57	.766
Computational thinking involves abstracting general principles and applying them to other situations	.345	1.163	.153	.039	.651	2.258	57	.028*
Comfort								
I can learn to understand computational thinking concepts	.172	1.353	.178	-.183	.528	.971	57	.336
I do not use computational thinking skills in my daily life	.155	2.207	.290	-.425	.735	.535	57	.594
Interest								
I think computational thinking is boring	-.586	2.161	.284	-1.154	-.018	-2.066	57	.043*
I think computational thinking is interesting	.293	1.325	.174	-.055	.641	1.685	57	.097
[a] 95% Confidence Interval of the Difference								
*p < .05								

The results of the paired t-test of the knowledge survey item, "CT involves abstracting general principles and applying them to other situations," indicated that posttest ratings differed significantly from pretest ratings, $t(57) = 2.258$, $p = 0.028$, $d = 0.296$, 95% CI [0.18, 1.154].

An attitude survey item that differed significantly from pretest ratings was, "I think CT is boring," $t(57) = -2.066$, $p = 0.043$, $d = -0.271$, 95% CI [-1.154, -.018]. Therefore, we can reject the null hypothesis that there is no difference in participants' mean pre and post ratings of these items. In this data set, these dimensions of knowledge and attitudes toward CT were measured on an interval scale of 1 to 7. On average, participants' posttest self-reported ratings of the knowledge item increased by approximately 0.345, and the item regarding attitudes decreased by 0.586. However, the

effect size was relatively small in both cases, as indicated by Cohen's *d* of 0.296 for knowledge and -0.271 for the attitude survey item.

The results of the paired *t*-test for preservice teachers' self-reported ratings of knowledge and attitudes toward AT are presented in Table 5.

Table 5
Results of Paired T-*Test of Knowledge and Attitudes Toward Assistive Technology*

| Survey Item | Paired Differences | | | | | | | Sig. (2-tailed) |
	Mean	*SD*	Std. Error Mean	Confidence Interval Lower[a]	Confidence Interval Upper[a]	*t*	*df*	
Knowledge								
How knowledgeable are you about assistive technology?	.456	1.226	.162	.131	.781	2.809	56	.007*
Comfort								
How comfortable do you feel assisting a student using assistive technology?	.246	1.057	.140	-.035	.526	1.754	56	.085
[a] 95% Confidence Interval of the Difference *p* < .05								

The results of the paired *t*-test of preservice teachers' knowledge of AT indicated that posttest ratings differed significantly from pretest ratings, *t*(56) = 2.809, *p* = 0.007, *d* = 0.372, 95% CI [0.131, 0.781]. Hence, we can reject the null hypothesis that there is no difference in participants' mean pre and post ratings of knowledge of AT. On the survey, knowledge was measured on an interval scale of 1 to 5, and on average, participants' posttest self-reported ratings of knowledge increased by approximately 0.456. The effect size was small to medium, as indicated by Cohen's *d* of 0.372. There was no statistically significant difference between participants' self-reported pre-and posttest ratings for attitudes toward using AT. Therefore, we cannot reject the null hypothesis that there is no difference in mean pre and post ratings for that item.

Integrating CT and AT in Future Classrooms

Research Question 2 asked, "Is there a significant change in the preservice teachers' comfort in using CT and AT in their future classrooms?" The results of the paired *t*-test for preservice teachers' self-reported ratings of future classroom preparation to use CT, AT, and robotics are presented in Table 6.

The results of the paired *t*-test of preservice teachers' perceived confidence to incorporate the concept of CT into their future classroom indicated that posttest ratings differed significantly from pretest ratings, *t*(57) = 2.382, *p* = 0.021, *d* = 0.313, 95% CI [0.069, 0.793]. Hence, we can reject the null hypothesis that there is no difference in mean pre and post ratings. On the survey, this item was measured on an interval scale of 1 to 5. On average, participants' posttest self-reported ratings of future classroom incorporation of CT concepts increased by approximately 0.431. The effect

size was small to medium, as indicated by Cohen's *d* of 0.313. There was no statistically significant difference between participants' self-reported pre- and posttest ratings for preparation to use AT. Therefore, we cannot reject the null hypothesis that there is no difference in mean pre and post ratings of participants' preparation to work with AT in the future.

Table 6
Results of Paired T-*Test of Future Classroom Integration*

	Survey Item	Paired Differences							
		Mean	SD	Std. Error Mean	Confidence Interval Lower [a]	Confidence Interval Upper [a]	t	df	Sig. (2-tailed)
CT	How comfortable do you feel about incorporating the concept of CT into your future classroom teaching environment?	.431	1.378	.181	.069	.793	2.382	57	.021*
AT	How prepared do you feel about working with someone who requires assistive technology?	.281	1.114	.148	-.015	.576	1.902	56	.062
[a] 95% Confidence Interval of the Difference									
*p< .05									

Qualitative Results

The qualitative findings of this study are organized by research question and theme and are supported by responses from open-ended survey items as well as student reflection assignments and design artifacts.

How Did Preservice Teachers Explain CT and Robotics?

Research Question 3 asked, "How do preservice teachers explain the concepts of CT and robotics after participating in the lesson?" Analysis of the open-ended survey items revealed that the preservice teachers explained CT largely by describing it as a problem-solving process. This included citing problem-solving attributes of CT, such as identifying, analyzing, and thinking about possible solutions to a problem. Other students made comparisons to computer scientists because they develop models for interaction between computers and people or software and hardware to break down information. Regarding the concept of robotics, the preservice teachers explained that robotics refers to the design, construction, operation, and use of robots and computer systems for their control, sensory feedback, and information processing. Some of the preservice teachers gave examples, like machines that take the place of or replicate human actions to assist people in their daily lives.

### *What Kind of Educational Robots Did Preservice Teachers Design?*

Research Question 4 asked, "What kind of educational problems did the robot designs of the preservice teachers address?" To answer this research question, we analyzed and coded student artifacts. The pictures that the

preservice teachers took of their robot designs and the responses to reflection questions regarding their robots were systematically analyzed. The analysis revealed that the types of educational problems the robots were designed to solve revolved around six themes:

- Helping English language learners (Figure 2)
- Helping students with hearing and vision challenges
- Helping students with reading challenges
- Robot helper as a teaching assistant
- School safety robots
- Emotional support and comfort robots (Figure 3)

The robot in Figure 2, the Read Bot, is designed to help students read. Features include eyeglasses to scan text, a camera, speakers, and a remote control, and it is waterproof.

Figure 2
The Read Bot: Assistive Robot Design to Help Students Read
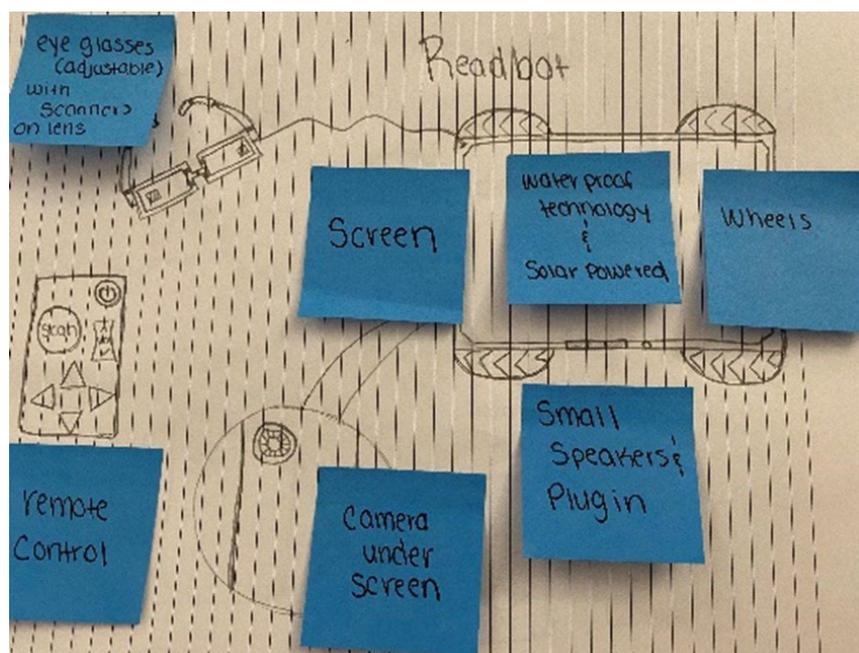
The robot in Figure 3, Friend Bot 2.0, is equipped with a surveillance camera and an anonymous box for notes. The robot can communicate by speaking or the use of American Sign Language.

These themes highlight how the participants envisioned the robots as being able to help with the educational basics by serving as teaching assistants and with literacy development, as well as supporting teachers with current educational issues such as school safety and emotional well-being. The participants also made the connection between assistive technology and educational robots by creating robots that could help make education more accessible to hearing and vision-impaired students.

Figure 3
Friend Bot 2.0: An Assistive Robot Design to Help Students From Bullying
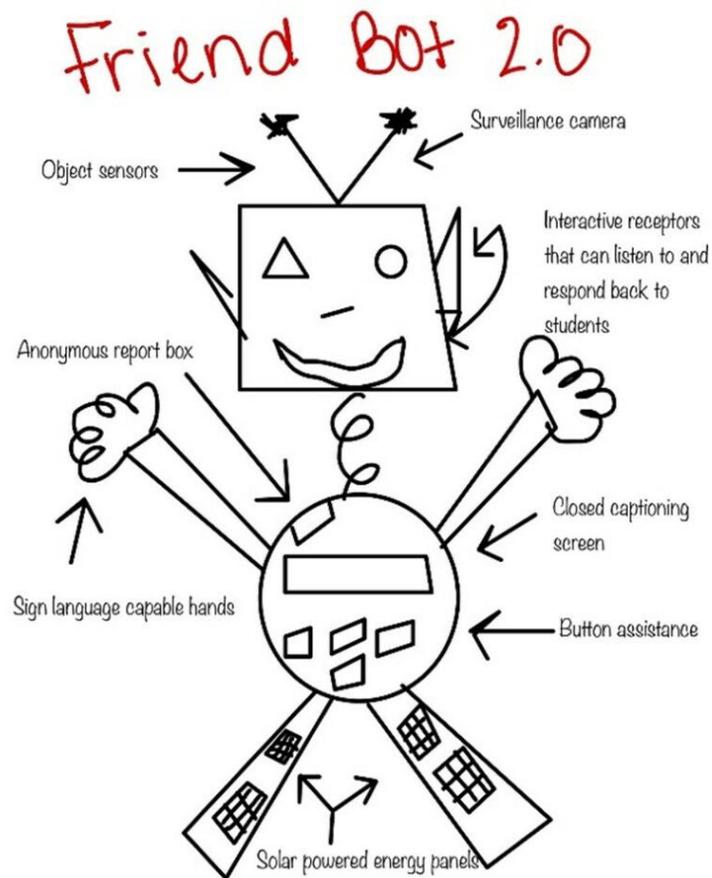
Discussion

The first purpose of this study was to examine how an online instructional module that integrated CT, AT, and robotics shaped preservice teachers' knowledge, attitudes, and comfort about integrating these concepts into their future classrooms. Prior research on integrating CT into teacher education demonstrated that implementing CT instruction can positively impact preservice educators' ability to conceptualize the use of CT in their future classrooms (Cheng et al., 2018). Adler and Beck (2020) found that CT experiences increase the intention to incorporate CT projects into their future instruction. The current study supported these findings and extended them by infusing AT concepts into an instructional module teaching students to apply CT skills. These assistive robots designed by students focused on solving a problem in the classroom while also addressing the needs of children with varying challenges.

Research Question 1 focused on preservice teachers' knowledge and attitudes toward CT and AT. Our quantitative findings indicated that blending instruction in CT with AT can positively shape students' knowledge and attitudes toward CT. We found statistically significant differences (*p* < .05) in pre-and posttest ratings for the knowledge-related item, "CT involves abstracting general principles and applying them to other situations," and the attitude item, "I think CT is boring." These findings suggest that the instructional module implemented improved self-reported CT knowledge and attitudes. The decreased mean rating for the attitude measure indicated that the students found CT to be less boring after completing the module.

We also found that four survey items assessing CT knowledge and attitudes did not produce statistically significant differences between pre- and posttest scores. The mean of the survey item, "CT involves thinking logically to solve problems," increased slightly from 6.34 to 6.41, which was relatively high overall, suggesting participants may have had a firm grasp of this definition of CT in the first place. The same goes for the item, "I can learn to understand CT concepts," which increased slightly (from 5.85 to 6.05) but not significantly, suggesting the participants may have had a relatively high level of confidence in their ability to learn about CT concepts before the lesson took place.

The item, "I do not use CT skills in my daily life," also increased slightly (from 2.98 to 3.14), which was interesting because participants felt more strongly that they do not use CT in their daily lives after completing the instruction. This finding raises the question of whether learning about CT through the instructional module helped students realize they had not been using it that much in daily life after all. Last, the CT item, "I think CT is interesting," increased slightly but not in a statistically significant way.

Our findings on the element of AT yielded mixed results. The results demonstrated that participants felt they gained knowledge about AT with a statistically significant (*p* < .05) increase in their rating of the item, "How knowledgeable are you about AT?" When looking at the statistics on AT attitudes, the value *p* = .085 implies there was not a statistically significant increase from pre -to posttest scores. This finding is consistent with Gronseth et al. (2010). They found that many preservice teachers receiving AT instruction reported that more instruction in AT was needed to increase students' comfort using AT in the classroom. Jones et al. (2018) and Park et al. (2021) found that Assistive Technology Labs that included hands-on experiences for preservice teachers improved comfort levels and attitudes.

These findings suggest that incorporating hands-on activities with AT in the online course may improve outcomes. For example, students could use the magnifier in Microsoft Windows to experience zooming in on the screen and download apps like Sullivan+ on their smartphones to take pictures of objects, then listen to audio descriptions of them to gain hands-on experience with AT tools for the visually impaired.

The focus of Research Question 2 was comfort in implementing AT and CT in a future classroom. Exploring the CT element of this question, another significant finding was that participants felt more comfortable about incorporating CT into their future teaching environment after completing

the instructional module. These findings are important, as they indicate the instructional module can positively shape preservice educators' knowledge and attitudes toward CT and this subject in the future. This could also prepare them to possess ISTE (2018) CT Competencies for Educators and implement the ISTE (2016) CT Standards for Students.

These findings specifically support research by Chang and Peterson (2018), who found that students who supported with the instructional components of a makerspace in addition to a CT unit were more readily able to conceptualize the use of CT in their future classrooms.

However, when it came to future classroom integration of AT, statistically significant differences in pre-and posttest ratings were not found (p = .062). As noted before, this finding is similar to the results of Gronseth et al. (2010), who found that students in teacher education were receiving AT instruction, but many reported that additional instruction in AT was needed to make students more comfortable using AT in the classroom. An investment in AT labs in colleges of education or field trips to local schools and centers could help give students hands on experience with AT tools and how they are integrated into the learning process.

The second aim of this study was to examine how preservice teacher education students explained the concepts of CT, AT, and robotics and to describe the types of educational problems the students' robot designs solved. Research Question 3 examined how preservice teachers explained CT and robots after completing the module. The participants mainly described CT as a complex problem-solving process. Robotics was mostly described in terms of design, construction, operation, and the interaction between humans and machines.

Research Question 4 revolved around the types of educational problems the robots designed by the preservice teachers addressed. Our findings showed that participants' robots were designed to help with traditional educational problems, such as challenges in reading and learning. These problems included English as a second language and assisting students with hearing and vision impairments. Safety, emotional support, and comfort were other major themes found in the types of educational problems the assistive robots were designed to solve. The latter findings may be attributed to concerns about school safety, due to the university's proximity to the Stoneman Douglas school shooting and media attention to this issue (British Broadcasting Corporation, 2022). This finding also raises the intriguing question as to whether artificial intelligence tools and robots have the potential to improve school safety, emotional support, and comfort distressed students.

Limitations

One limitation of this study was that, because students were required to complete the assignment as part of the module, they may have felt obligated to participate in the voluntary research, even though participation was optional and not linked to their grade. Another limitation was that two of the four researchers in this study were instructors of the courses in which the data was collected. This may have led to a biased student response if they assumed the instructor would favor

certain responses. For example, it is possible that students could have intentionally responded to measures on the pretest and posttest surveys in a certain way to please their instructor. Another important limitation to consider is research bias, since some investigators were engaged in research in their own courses. It is worth noting, however, that a graduate research assistant (not involved in the course) served as the lead qualitative analyst and a researcher from outside the university engaged in all phases of data analysis.

Another limitation of these findings is these participants were all in online classes. If students in face-to-face or blended courses were included in this study, the measures of AT and CT measures might differ.Yet, another limitation of this study is that the students who participated in the module may have varied educational backgrounds and exposure to the concepts of AT and CT or may or may not be more experienced in taking coursework online, which was the mode of instruction in this study. Such variations may influence students' ability to scaffold new information upon prior knowledge when completing the lesson or successfully navigating an online course.

Our subject pool was relatively small (n = 59). Future studies of AT and CT integration into online instruction could examine larger samples and possibly explore differences among learners based on experience with AT, CT, and online learning. Also, the external validity of this study is not known because the scope of this study focused on one university. Therefore, the study results may only be generalized to the limited population of preservice teacher education students.

Conclusions

Mouza et al. (2016) found that to prepare preservice teachers to infuse CT in their future classrooms, their curriculum needs to include computing tools, vocabulary, and practices to understand CT. This research highlights how the instructional module we implemented positively impacted participants' knowledge of CT by coupling the instruction on CT and AT concepts with an inexpensive robot design activity. Students could apply what they learned by breaking down an educational problem, accessibility issues, and creating their robot while detailing their thought process through diagramming and responding to reflection questions. At the same time, our findings also imply that preservice teachers need more instruction and experience with AT to be comfortable using AT in their future classrooms. Educational leaders may use the information from this study to examine their programs to better prepare future teachers for inclusive classrooms, including a deeper focus on CT and AT and expanding hands-on AT activities.

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