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EXPLORING THE DEVELOPMENT OF PRE-SERVICE TEACHERS' KNOWLEDGE AND ATTITUDES TOWARDS INTEGRATING COMPUTATIONAL THINKING AND ROBOTICS INTO THE CLASSROOM

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Abstract
This paper presents an introductory computational thinking (CT) module that can be implemented into teacher education curricula. The researchers examined how the integration of CT and robotics instruction into an undergraduate instructional technology course influenced pre-service teachers' understanding of CT and robotics and their attitudes towards adopting these tools in their future classrooms. The online module was developed as a result of a collaboration between computer science and education faculty from two universities. A total of 93 students participated in the study. The course was delivered during the spring, summer, and fall semesters of 2020 via distance learning at a large public university located in Florida. Data for this study were collected using a pre-and post-test survey that was created with Qualtrics software. This paper describes how the CT and robotics concepts were taught and examines the influence of the instruction on participants' knowledge and attitudes of CT and robotics and their integration into the classroom.

Keywords: computational thinking, distance education, preservice educators, robotics

Introduction

Globally, education systems are responding to our rapidly expanding technology-connected world by incorporating Computational Thinking (CT) skills into classrooms to support this transformation. Wing 2017, p. 7, defines CT as "the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer-human or machine—can effectively carry it out". Wing (2008) goes on to suggest that computational thinking is a fundamental analytical skill that every child should be taught, just as reading, writing, and arithmetic are. Computer science education includes CT in the curriculum, but K-12 teacher educators are less familiar with what CT entails (Yadav et al., 2017).

The importance of adding CT to the K-12 curriculum has led the International Society for Technology in Education (ISTE), the leading organization in the development of technology standards for students, teachers, and educational leaders, to develop CT standards (International Society for Technology in Education [ISTE], 2021). The standards are broken down into five categories: (a) computational thinking (learner), (b) equity leader (leader), (c) collaborating around computing (collaborator), (d) creativity and design (designer), and (e) integrating computational thinking (facilitator). The standards charge teachers to improve their practice by developing an understanding of computational thinking and how to apply it in cross-disciplinary ways (ISTE, 2021). The standards also indicate that CT can create opportunities for personal expressions and train students to identify opportunities to apply CT in their environment (ISTE, 2021).

In a literature review on teacher preparation and CT, Mason and Rich (2019) noted a lack of teacher training for computing, especially in elementary education. This research addresses these issues by describing instructional activities that teachers can easily adapt to introduce CT and robotics concepts to their students and examining its influence on pre-service teachers' knowledge and attitudes towards integrating CT and robotics into the classroom.

Literature Review

To create a generation of future computer scientists, data analysts, and computer engineers, children need to be exposed to computational thinking skills (CT) earlier in their academic journey. Computation skills are becoming one of the most important employability skills a student can have as most jobs in the future will be using some form of technology. Interest in pursuing advanced degrees in science emerges before middle school; therefore, elementary education teachers are crucial for generating interest in computers and programs by introducing the topic at younger ages than it is currently (Alexiou, et al., 2019). Understanding CT is important in developing problem-solving skills for many disciplines beyond coding; therefore, pre-service teachers with a good understanding of CT have indicated higher rates of willingness to use STEM-based teaching and the use of interdisciplinary instructional approaches (Günbatar et al., 2019). Most importantly, CT skills are important as they are the prerequisite to the development of coding skills needed to create the future workforce (Hunsaker, 2019).

Computational skills consist of several components which promote critical thinking skills. The Center for Discrete Mathematics and Theoretical Computer Science has identified four key techniques which allow the use of computers to solve complex problems (Center for Discrete Mathematics and Theoretical Computer Science, n.d.). The first technique is decomposition which involves breaking down the components of the complex problem into smaller segments. The second technique is the recognition of patterns to determine similarities among or within different problems, which allows for quicker resolution. The third technique promotes the elimination of irrelevant information to allow the focusing on the important information through abstraction. Finally, is the development of a series of step-by-step procedures to solve similar types of problems using algorithms.

Before computational thinking skills can be fully integrated into K-12 classrooms, several items need to develop including a defined set of CT learning strategies, a set of metaphors to promote understanding, pedagogical strategies and technology for teaching CT, professional development for teachers, and assessment of CT competencies (Angeli & Giannakos, 2019). With the increasing demand that CT is introduced in elementary schools at younger ages, school districts need to have elementary education teachers that are prepared to teach the students these skills. Currently, K12 students are taught how to use computers, applications, and internet resources. Students need to be taught how to use computational thinking and computer programming to solve complex problems (Alexiou, et al., 2019). Pre-service teachers are becoming teachers with a weak understanding of CT and often confuse CT with using technology in general (Bower & Falkner, 2015). Therefore, teachers currently do not know how to build CT expertise in their students by shifting to using technology to solve problems (Chang & Peterson, 2018).

Recently, some researchers have attempted to incorporate instruction in CT and robotics into teacher education and study the impact of doing so (Adler & Black, 2020; Hestness et al., 2018; Kong et al., 2020; Mouza et al., 2017). Adler and Beck (2 020) developed an introductory computer science course and expanded its use to foster CT in pre-service teachers. In a mixed-methods examination of the initiative, the researchers found that self-efficacy in CT skills increased in all students, and education students also increased their confidence in coding and expressed an intention to integrate CT in their classrooms (Adler & Black, 2020). Kong et al. (2020) designed and evaluated a CT professional development program for in-service primary teachers. Their findings indicated that participants increased their understanding of CT knowledge and practices (Kong et al., 2020). Professional development has proven to be an important tool in the development of both an understanding of CT with both pre-service and elementary education teachers. Through professional development, participants can connect their instructional knowledge to policies, theoretical notions, and instructional strategies connected to CT pedagogical (Hestness et al., 2018). Additionally, infusing CT into a pre-service teacher's educational technology course influenced their dispositions about CT and increased their knowledge about CT, which allowed them to combine the content and the pedagogy to create activities resulting in a superficial understanding of CT (Mouza et al., 2017). The result of that study tied back to Angeli & Giannakos (2019) point that the field needs to identify pedagogical strategies that will promote knowledge in the field.

The challenge in teaching CT skills is that most teachers do not have computer science skills. Schools typically have limited resources for teaching the core curriculum. To address these limitations, the field has developed unplugged activities. These activities promote computational techniques of decomposition, pattern recognition, abstraction, and algorithms without the use of a computer. The approach has been successful with students using unplugged activities demonstrating higher levels of CT knowledge as compared to those not engaging in the lessons (Brackmann et al., 2017). This study explores how integrating an unplugged CT and robotics module into an undergraduate instructional technology course shaped students' understanding of CT and robotics and their attitudes towards adoption in their future classrooms. In doing so, the following research questions were asked:

1. What is the influence of the instruction on pre-service teachers' knowledge and attitudes towards computational thinking?
2. What is the influence of the instruction on pre-service teachers' knowledge and attitudes towards robotics?

Methodology

Data Collection

Data for this study were collected using a pre-and post-test survey that was created with *Qualtrics* software. The survey contained 19 items, though not all were included in this analysis. The items examined in this study included demographic and background information about the participants. Additionally, several items adapted from the instrument utilized by Yadav et al. (2014) were adapted to assess participants' perceived knowledge of and attitudes towards computational thinking and robotics in three categories: Definition, Comfort, Interest, and Use in the classroom.

Upon approval of the university institutional review board, the surveys were administered electronically within the instructional technology course via a learning management system. Students were provided with a link to the pre-test survey before taking the CT and robotics instructional module, and the post-test survey was presented after the instruction. Although all students in the courses took the surveys, participation in the research was voluntary, and thus only students who consented to do so were included in this study.

Data Analysis

Data from the survey were entered into SPSS® 27 software for analysis. Descriptive statistics for self-reported demographic and background variables were calculated to paint a picture of the participants. The survey items regarding participants' self-reported ratings of their knowledge and attitudes toward CT and robotics before and after the instruction were summarized by calculating descriptive statistics. Simple differences between pre-and post- ratings on these items were calculated to examine if changes in participants' ratings of their knowledge and attitudes towards CT and robotics had occurred.

Participants

A total of 93 students enrolled in an introductory undergraduate instructional technology course participated in the study. The instruction was delivered during the spring, summer, and fall semesters of 2020 via distance learning at a large public university located in the southeastern United States. Most of the participants indicated their gender was female (N=79) and 14 were male, which is a common occurrence in education courses. A majority of participants were in the traditional college age range of 18 to 22 (86%), and 7.5% were in the range 23 to 27, 7.5% in the range of 28 to 32, and 3.2% were age 30 or greater. Also, most of the students were pursuing a degree in the education field (83.8%), including early childhood, elementary, chemistry, English, mathematics, social studies, and exceptional student education, majors as shown in Table 1.

Table 1

Participants by Degree Program

Degree Program	N	%
Bachelor in Early Child Care and Education	18	19.4
Bachelor of Arts in Exceptional Student Education	9	9.7
Bachelor in Chemistry Education	1	1.1
Bachelor in Elementary Education	31	33.3
Bachelor in English Education	7	7.5
Bachelor in Math Education	2	2.2
Bachelor in Social Science Education	10	10.8
Pursuing a different degree or course of study	15	16.2
Total	93	100

As for the participants' point in their program of study at the university, 14 indicated freshmen, 38 sophomores, 29 junior, and 12 senior on the survey.

Description of the Instructional Module

The study setting was an instructional technology class consisting of predominantly pre-service educators preparing to become teachers. This class is often one of the first classes students take within their degree program. To teach computational thinking (CT) and to introduce them to using robots in the classroom, students were presented with instructional materials, including PowerPoint presentations, videos, and online readings. The lesson was designed to meet the International Society for Technology in Education (ISTE) Computational Thinking Competencies for educators and CT Standards for Students (2016). In the online module, students formulate problem definitions suited for technology-assisted solutions, break problems into component parts, and use algorithmic thinking to develop descriptive models. The students are then given an assignment in which they create a robot. Students were instructed to design a robot for a purpose that will help solve a societal problem or address a need in one of the following areas: (a) education, (b) health care, (c) aging, and (d) the environment.

Students used MS Word to create their robot designs while labeling its parts and describing its features. By adding shapes, word art, text boxes, and images. The students created annotated diagrams of their robots, their parts, and their purposes. Upon completion of the diagrams, students reflected upon the experience by responding to the following written questions:

1. What service does your robot do, and why is this important to the societal area?
2. What features does your robot need (hardware, software, anything additional) to successfully perform its functions?
3. How does each note you have placed on your robot relate to the features it needs?
4. What types of physical obstacles would your robot have to overcome?
5. What types of psychological challenges do people have to overcome to accept your robot service?

Results

Computational Thinking Knowledge and Attitudes

The survey items used to assess CT knowledge and attitudes were measured on a 7 point Likert scale. Slight gains in the two items relating to participants' knowledge of CT were observed. Differences between the pre-and post-test ratings for the items in the dimension of comfort were mixed. For the items " I do not think I can apply knowledge of computational thinking to solve problems" and "I do not use CT skills in my daily life," there were small decreases in the overall mean ratings from pre- to post-test. This finding was promising because, in this case, a lower mean suggests the participants were more comfortable with CT after completing the lesson. Also, the comfort item "I can learn to understand CT concepts" increased slightly. However, the item "I am not comfortable with learning CT concepts" increased by a greater margin, suggesting the students did not feel more comfortable with learning CT after the lesson. For the three items relating to interest, there were increases in the ratings of items that were expected to increase (those that indicated a positive interest). At the same time, there was a decrease in the item "I think CT is boring," which was another promising finding because this was the desired outcome. Lastly, there were also mixed results for the items relating to the classroom. The item "CT can be incorporated in the classroom by using computers in the lesson plan" decreased slightly, which suggested that students learned that CT could be integrated into the curriculum through "unplugged" activities without relying on the use of expensive technology devices. The items relating to integrating CT into the classroom through problem-solving and thinking logically both increased slightly. The mean pre-test, post-test, and differences for participants' ratings of CT knowledge and attitude items are shown in Table 2.

Table 2

Mean Pre-test, Post-test, and Differences for Participants Ratings of CT Knowledge and Attitudes

Survey Item	Pre-test	Post-Test	Difference
Computational thinking involves thinking logically to solve problems (Knowledge)	6.25	6.30	.0330
Computational thinking involves abstracting general principles and applying them to other situations (Knowledge)	6.09	6.16	.0330
I do not think I can apply knowledge of computational thinking to solve problems (Comfort)	2.62	2.46	-.1429
I am not comfortable with learning computational thinking concepts (Comfort)	2.50	2.89	.4176
I can learn to understand computational thinking concepts (Comfort)	6.03	6.09	.0549
I do not use computational thinking skills in my daily life (Comfort)	3.10	2.84	-.2637
I think computational thinking is boring (Interest)	3.26	3.07	-.2308
The challenge of solving problems using computational thinking appeals to me (Interest)	4.71	5.05	.3516
I think computational thinking is interesting (Interest)	4.99	5.29	.3297
I will voluntarily take computational thinking courses if I were given the opportunity (Interest)	4.13	4.35	.2637
Computational thinking can be incorporated in the classroom by using computers in the lesson plan (Classroom)	5.89	5.86	-.0220
Computational thinking can be incorporated in the classroom by allowing students to problem solve (Classroom)	6.09	6.09	.0110

Computational thinking involves thinking logically to solve problems (Classroom)	6.25	6.30	.0330

Robotics Knowledge and Attitudes

The survey items used to measure robotics knowledge and attitudes were also measured on a 7 point Likert scale. The analysis indicated that the participants' mean ratings of all of the items we expected to increase after the instruction did so, and ratings of the items we expected to decrease were lower. Generally speaking, the items for which decreased mean ratings were observed were those that were negatively worded, such as the item in the comfort dimension "I do not use robotics skills in my daily life." The mean pre-test, post-test, and differences for participants' ratings of robotics knowledge and attitude items are shown in Table 3.

Table 3

Mean Pre-test, Post-test, and Differences for Participants Ratings of Robotics Knowledge and Attitudes

Survey Item	Pre-test	Post-Test	Difference
Robotics involves the design of machines that can sense the world and act on it (Knowledge)	5.85	6.25	.4444
Robotics involves the design of machines that can make decisions based on computations (Knowledge)	5.93	6.09	.4333
I do not think I can apply knowledge of robotics to design robots (Comfort)	3.62	2.62	-.5000
I am not comfortable with learning robotics concepts (Comfort)	3.54	2.50	-.2667
I can learn to understand robotics concepts (Comfort)	5.21	6.03	.4222
I do not use robotics skills in my daily life (Comfort)	4.82	3.10	-.8111
I think robotics is boring (Interest)	3.61	3.26	-.3111
The challenge of solving problems using robotics appeals to me (Interest)	4.21	4.71	.4333
I think robotics is interesting (Interest)	4.54	4.99	.4111
I will voluntarily take robotics courses if I were given the opportunity (Interest)	3.42	4.13	.8444
Robotics can be incorporated in the classroom by using computers in the lesson plan (Classroom)	5.04	5.89	.5667
Robotics can be incorporated in the classroom by allowing students to problem solve (Classroom)	5.55	6.09	.4222

How comfortable do you feel about incorporating the concept of robotics into your future classroom teaching environment (Classroom)	5.85	6.25	.4444

Conclusion

The purpose of this study was to examine the influence of instruction on CT and robotics concepts and classroom integration on pre-service teachers' knowledge and attitudes towards future classroom implementation. Overall, the mean reported ratings of the participants' CT and robotics knowledge and attitudes that we hoped would increase as a result of the instruction showed gains, and those in which decreases were desirable declined. These findings were similar to those of Mouza et al. (2017), who found that instruction in CT positively influenced pre-service teachers' knowledge and dispositions in the area, as well as Kong et al., who found that a professional development course in CT increased participants knowledge and understanding of CT. Teacher educators and leaders may use the information from this study to examine their programs to prepare future teachers to develop a deeper understanding of how to integrate CT and robotics into the curriculum.

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