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Teaching Robotics with Problem Based Learning to Improve Students' Computational Thinking Skills, Coding Skills and Positive Affects

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Abstract

This study aimed to examine the effect of the teaching of robotic coding designed according to the problem based learning (PBL) approach for secondary school students (11-12 ages) on their coding skills, computational thinking (CT) skills and positive affects. This study used a 'pretest-posttest quasi-experimental model with the control group' and the study group consisted of 178 fifth-grade secondary school students. During the research process, 104 students in the experimental group were taught using the 'teaching of robotic coding with problem based learning method', while 74 students in the control group were taught using the 'teaching of robotic coding with the traditional learning method' for five weeks. According to the results obtained from the research, it was seen that both the experimental and control groups' coding skills and CT skills increased significantly. However, the experimental group students' coding and CT skills were significantly more developed than those of the control group. In addition, during the treatment, each of the problem scenarios given to the experimental group according to the PBL approach was found to have significantly increased the positive affects of the students. As a result of the discussion on literature and research findings, it was said that PBL and CT skills can be bidirectional. This claim needs to be further explored.

Key words: *coding skills; computational thinking; educational robotics; positive affect; problem-based learning; problem solving; robotic coding*

Introduction

In the 21st century, where access to digital environments is so easy, which skills can learners acquire that can prepare them better for the future? Or, which skills could they employ to solve life problems with the help of technology, which will also provide an opportunity for them to develop? With the rapid transformation of life into digitally-enabled environment, academics and educators have led us to focus on what skills the 'growing generations' will need in the future (Lockwood & Mooney, 2017; Sonnleitner et al., 2014). In the report by Organization for Economic Co-operation and Development (OECD), prepared by Ananiadou and Claro (2009), some skills were listed as learner characteristics. These skills were the learner traits that students were expected to exhibit as skills rather than knowledge to be owned, such as creativity, critical thinking, and problem-solving (Bocconi et al., 2016). It is more demanding than ever that students can solve complex problems (Sonnleitner et al., 2014). The focus is on the question of how to 'acquire' these skills that students are expected to acquire and exhibit in their lives (Kafai & Burke, 2013; Seow et al., 2019; Sonnleitner et al., 2014). Then, some literacy skills, including computational thinking (CT), that future citizens are expected to possess were presented at the World Economic Forum (World Economic Forum, 2015). All these developments had a meaning: we needed to add CT to students' basic skills, such as reading, writing, and mathematics (Wing, 2006).

Wing's (2006) definition of CT states that "it involves solving problems, designing systems, and understanding human behaviour, by drawing on the concepts fundamental to computer science (CS)". Wing (2011) then revised his definition, claiming "CT is the thinking processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent." CT is the ability to use algorithmic methods to identify and solve problems, focusing on the real problems in the world (Shute et al., 2017). CT thinking abilities and techniques help develop problem-solving skills (Grover & Pea, 2013; Wing, 2008). Wing (2006) emphasized that CT could be used in many areas of daily life and should be taught to students at younger ages. When progress from that time to the present is examined, CS training has been more popular, but it is noted that worldwide CT training remains at the infancy stage when the stage of integration into K-12 is considered (Lockwood & Mooney, 2017).

CT is a fundamental skill for students (Zhong et al., 2016) and CS was first included in K-12 curricula worldwide to enable students to acquire this skill (Balanskat & Engelhardt, 2015; Brown et al., 2013). CS was integrated into the curriculum through the projects in the United States (CSTA, 2011), Taiwan (NAER, 2018), Australia (Australian Curriculum, Assessment, Reporting Authority, 2013) and Türkiye (FATİH, 2012). The National Science Foundation (NSF) has allocated $120 million in the United States for integrating CS into the curriculum (Kale et al., 2018).

Movement of Enhancing Opportunities and Improving Technology (FATİH Project) was initiated in Türkiye in 2010. FATİH Project is a comprehensive education movement that aims to improve access to information technologies (IT) tools in schools. FATİH

Project is a multi-dimensional project that aims to provide IT hardware, software, network infrastructure and Internet access to all schools and to develop e-content (MEB, 2021). In line with these goals, the name of the 'Information Technologies' course was updated as 'Information Technologies and Software' in 2012. As Kafai and Burke (2013) claimed, these experiences reveal that teaching of programming returned to curricula in schools after the 1980s. However, it is worth noting here that this return was released with some differences. The first notable difference was that "CT is a fundamental skill for everyone, not just for computer scientists" (Wing, 2006). In other words, currently, CS training is not a complexity in which students should learn programming 'as a goal' (Wu & Su, 2021). It is integrated in a block structure through which students can make productions by coding, and solve problems using them 'as tools' (Garcia-Penalvo & Mendes, 2018). There is an ongoing tendency towards including CT rather than CS in the K-12 curriculum (Tran, 2019). CT refers to the cognitive process of problem-solving (Wing, 2008). Coding is one of the keyways to reach CT (Wu & Su, 2021). Therefore, the phrase 'coding' is preferred to programming. Students are expected to be producers in this process to solve real-life problems (Garcia-Penalvo & Mendes, 2018). The final difference is that they experience a concrete CT process through which they produce, solve problems and debug (such as observing unwanted robot movements) (Wing, 2011). In the process, physical robot courses were integrated into the elementary education stage (although it may vary from country to country, starting from the age of 10-11) (Wu & Su, 2021). When we look at the reflection of this on the practices in Türkiye, we see that the 'Information Technologies and Software' course content was updated in 2018 by adding coding teaching (TTKB, 2018).

CT is not just an encoding business, as it is associated with the outputs of the well-planned coding practices (Garcia-Penalvo & Mendes, 2018). Teachers also need well-planned coding examples to integrate CT into their instructional content (Israel-Fishelson et al., 2021; Lockwood & Mooney, 2017). These well-planned coding examples imply using methods that could simulate simple everyday problems associated with life (Wu & Su, 2021). Problem-based learning (PBL) could be one method to simulate this situation. There have been few studies in the relevant literature related to teaching robotic coding based on the PBL approach. As part of this research, detailed lesson plans were created using the PBL method to improve the CT skills of secondary school students. These lesson plans are expected to be the resources that teachers can benefit from. In addition, the lesson plans prepared based on the PBL method were applied, and students' CT skills, positive affect states, and coding skills were tested using the experimental method.

Purpose

This research aims to find out the effect of the teaching of robotic coding designed according to the PBL approach on the coding skills, CT skills, and positive affects of students in secondary schools.

For the stated purpose, answers to the following research questions were sought:

1. What is the effect of the teaching of robotic coding designed in line with the PBL approach on coding skills?

2. What is the effect of the teaching of robotic coding designed in line with the PBL approach on CT skills?

3. How is the change in students' positive affect states related to problem scenarios in the teaching of robotic coding designed in line with the PBL approach?

Literature review

Coding with robotics and computational thinking

Collaborating with artificial intelligence and smart technologies in life and work environments has led to changes in the skills expected from individuals. The International Society for Technology in Education (ISTE) has officially announced that CT skills have been expected from students since 2016 (ISTE, 2016). The CT highlights coding skills in CS courses (Kale et al., 2018). CT is much more than coding, but coding is an important tool that could ensure the development of CT skills (Voogt et al., 2015). Coding helps individuals acquire higher-order thinking skills such as problem-solving, creative thinking, and collaborative work, more than learning to write a code (Fessakis et al., 2013).

While teaching coding to students, many concepts and processes remain abstract for students, and they have difficulty visualizing the information. At this point, the teaching of robotic coding, in which mechanics and coding are used together, emerged in the literature. Using robots in the teaching of coding embodies the coding-related concepts and increases students' coding skills by making the process more enjoyable and interesting (Çankaya et al., 2017; Martin-Ramos et al., 2018; Özdemir et al., 2009; Soykan, 2018; Şimşek, 2018; Xia & Zhong, 2018), improves their problem-solving and critical thinking skills (Merlo-Espino et al., 2017; Sung et al., 2017), increases their academic achievement and perceptions of self-efficacy (Kasalak, 2017).

Today, using robot coding software and physical and virtual robot coding environments to teach robotic coding is quite popular. The mBlock, produced by Makeblock company, consists of Scratch 2.0 and 3.0, robotics and Arduino platforms, which allow graphics-based visual coding. The current version, which supports nearly 20 languages, is also compatible with different operating systems (Makeblock, 2019). A screenshot of the mBlock block-based visual coding environment and mBot robot are shown in Figure 1.

Robotics and coding lead individuals to CT, covering problem-solving processes (Lye & Koh, 2014). CT should not be considered just a problem-solving skill. Wing (2008) claims that CT should not be a new name for the problem-solving process, and that it also includes different processes such as critical thinking, algorithmic thinking and abstraction, as well as problem-solving.

Coding is a way of encouraging CT. The logic behind using coding and robotics to improve CT skills emphasizes various CT components, such as problem analysis, abstraction, generalization, and debugging (Shute et al., 2017). The coding process allows individuals to make multiple attempts and use multiple problem elements to develop, test, and improve solutions to challenging tasks, at the same time providing an opportunity to apply CT skills (Kale & Yuan, 2021). Many studies show that education affects CT skills positively (Akçay et al., 2019; Alsancak Sirakaya, 2018; Erdem, 2018; Garneli & Chorianopoulos, 2019; Zhaoa & Shute, 2019), and students found this process fun and engaging.

Figure 1. mBlock visual coding environment and mBot robot

However, combining coding training with robotics, which focuses on problem-solving skills to prepare students for their future professional careers, allows students to monitor their thoughts concretely. Students use their cognitive skills when writing codes and identify errors in their thinking by monitoring their robot movements. Educational robotics has recently been used for numerous educational goals, including improving CT skills (Stewart et al., 2021). In addition, robotics is an interdisciplinary way to integrate and implement CT (Shoop et al., 2016). Using robots in the teaching of coding increases students' CT skills (e.g., Baek et al., 2019; Bers et al., 2019; Chalmers, 2018; Constantinou & Ioannou, 2018; Luo et al., 2020; Roussou & Rangoussi, 2020; Sullivan et al., 2017). These studies reveal that educators can use robotics in the curriculum beginning from elementary school to improve their CT skills (Stewart et al., 2021). Scripted, arranged, planned curricula and practices are needed to develop CT skills (Cutumisu & Guo, 2019; Kale et al., 2018).

Since 2017, an increasing number of studies have been carried out on robotic coding and CT. It is observed that the majority of these studies are carried out at the preschool and primary school levels. This study, conducted with students in the first years of secondary school (11-12 ages), presents the results of applications made for different levels found in the literature.

Problem based learning and CT

Problem-solving is the basic skill underlying CT and one of the most important skills (Van Merriënboer, 2013). In order for teachers to integrate CT into their teaching processes, they need to know the nature of problem-solving and CT (Kale et al., 2018). Problem-solving covers "understanding, planning & monitoring, executing and self-regulating" (Mayer & Wittrock, 2006). The nature of CT covers "confrontation, decomposition, pattern recognition, abstraction, algorithm and analysis" (Grover & Pea, 2013; Kale et al. 2018). When examining the available alternatives in problem-solving, CT identifies the characteristics that stand out. During the problem solving process, the planned action steps are carried out. The automation system for the steps to solve the problem is carried out in CT. In problem-solving, when the controls and decisions are taken, testing, debugging and troubleshooting are performed in CT. These progressive structures of both problem-solving and CT require course designs to be made by scripting the teaching processes in developing CT skills (Israel-Fishelson et al., 2021; Lockwood & Mooney, 2017; Steward et al., 2021). For example, Chen et al. (2017) organized the robotics curriculum as "writing a code on a piece of paper, testing the code on a virtual robot, and then running the tested code on a physical robot".

PBL is a student-centered pedagogical strategy that provides students with guidance and resources, the opportunity to reflect on their knowledge and problem-solving skills, and compares them with unstructured problem situations related to real-life experiences (Hoffman & Ritchie, 1997). PBL supports lifelong learning by aiming to provide students with the ability to learn how to learn. In the PBL approach, the problem is used to motivate learners, to initiate and develop learning by putting the problem in the centre. The curriculum can be used when writing PBL scenarios. In this process, concepts in the curriculum can be explained to students according to the problem situation (Gallagher et al., 1995).

Courses designed with the PBL approach are known to have increased students' achievement (e.g. Alper & Deryakulu, 2008; Gao et al., 2019; Gürlen, 2011; Moralar, 2012; Şendağ, 2008). The PBL approach is known to have increased students' creative thinking skills (Yaman & Yalcin, 2005), problem-solving skills (Denis & Hubert, 2001; Tseng et al., 2008), emotional intelligence (Caballero-Gonzalez et al., 2019; Luy-Montejo, 2019), critical thinking skills (Saputra et al., 2019; Sierra Rativa, 2019), and motivation (Ersoy & Baser, 2010; Lykke et al., 2014). Chen et al. (2017) applied the robotics curriculum developed based on problem-solving at the primary school level for six months. They found that students' CT skills improved. Caballero-Gonzalez et al. (2019) prepared lesson plans using problem-solving activities in their research. They used educational robotic kits (Bee-Bot) in their research and found that their primary school students improved their social interaction and CT skills. Similarly, Angeli and Valanides (2019) produced problem-solving scenarios in their research. They used robot kits (Bee-Bot) in their lessons, which they taught in line with the scenarios. With this research, they found that the students' CT skills improved. Kale and Yuan (2021) examined the coding lesson plans for third-year elementary schools on the code.org website, and those problem-solving teaching methods were used to improve CT and problem-solving skills. Those lesson plans supported these skills.

In this scripted curriculum process, teachers should have a good understanding of the problem-solving nature of CT (Voogt et al., 2015) and present their learning content through problem scenarios (Kale et al., 2018). Presenting learning content through problem scenarios will facilitate teachers' job, and support learning goals (Kale et al., 2018; Lye & Koh, 2014). There is a need to produce and test such course designs for the development of CT skills.

Positive affect and robotics

Positive affects such as being interested, excited, strong, enthusiastic, proud, inspired, determined, attentive, and active, make people feel happy and contribute positively to their success (Lyubomirsky et al., 2005). Positive affects also allow a person to think in different ways and be more creative and fun, making them feel safe without feeling threatened (Fredrickson, 1998, 2001).

Şişman and Küçük (2019), who examined the perceptions and experiences of pre-service teachers in the educational robotics courses, found that enjoyment and motivation are strongly correlated. Haapasalo and Samuels (2011), on the other hand, argued that fun through robotics in mathematics education could increase students' motivation to learn. Stewart et al. (2021) also claimed that motivated students would demonstrate better skills in problem-solving. This means that task continuity is required in developing students' problem-solving skills (Jõgi & Kikas, 2016), and students with higher motivation are often more persistent in performing an assigned task (Hardre & Reeve, 2003). When the ways to access results that require long-term operations such as motivation were examined, they were associated with positive affects such as enjoyment, hope, and pride (Pekrun et al., 2002). However, the studies investigating the relationship between learning enjoyment and motivation claim there is a positive relationship between these two variables (Stewart et al., 2021).

Ensuring a positive affect in learning environments is considered valuable. With the robots used in the teaching of coding, students can touch electronic circuit systems and the robot physically. Thus, they find the lessons funnier and more engaging (Eteokleous-Grigoriou & Psomas, 2013; Stewart et al., 2021). Similarly, using robots in teaching coding has been revealed to increase students' motivation for the lesson and create more long-lasting and meaningful learning (Ersoy et al., 2011). Researchers have argued that educational research needs to focus on the ways to encourage positive affects in students. It is also recommended that further experimental studies be conducted on developing students' positive affects (Pekrun et al., 2002).

Methodology

This study used a quasi-experimental design with a pre-test - post-test control group. The research design is presented in Table 1.

Table 1
Research Design

Group	Pre-Test	Robotics Teaching (5 weeks)	Post-Test
Experimental Group	Coding Skill, Computational Thinking Skill	Problem-Based Learning Method Positive Affect	Coding Skill, Computational Thinking Skill
Control Group	Coding Skill, Computational Thinking Skill	Traditional Method	Coding Skill, Computational Thinking Skill

As seen in Table 1, robotics teaching was carried out with the PBL method in the experimental group and with the traditional method in the control group. The experimental and control groups' coding skills and CT skills were measured before and after the robotics teaching. In addition, positive affect states were identified during the experimental process of the experimental group.

Participants

The study group of the research consists of 190 fifth-grade students (11-12 ages). However, 12 students were excluded in the evaluation stage of the research data as they did not receive one or more tests administered in the research process. The research was conducted with 178 students taking the Information Technologies and Software course, 104 in the experimental group and 74 in the control group.

Data collection tools

The coding skill test, CT skills scale and positive affect scale were used as data collection tools in the research.

Coding skills test

The researcher developed the coding skills test. The coding skills test had been prepared by considering the activities aiming to teach coding among the fifth grade learning objectives of the Information Technologies and Software course in the curriculum. The development stages of the test are shown in Figure 2.

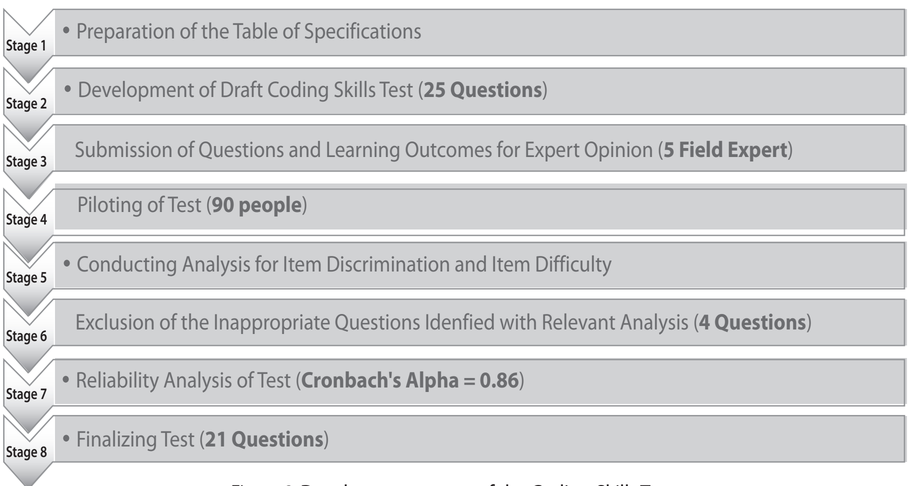

Figure 2. Development stages of the Coding Skills Test

The mean item difficulty index of the prepared test was found to be 0.53, and the mean item discrimination index was found to be 0.61. Cronbach's Alpha reliability coefficient of the test was found to be 0.86. The developed test was applied to all students participating in the research as a pre-test and post-test.

CT skills scale

'The Self-Efficacy Perception Scale for Computational Thinking Skill (CTS)' developed by G*ü*lbahar et al. (2019) was used to determine the impact of the teaching of robotic coding designed according to the PBL approach on students' CT skills. The 3-point Likert scale consists of 36 items. Cronbach's Alpha reliability coefficient of the scale was found to be 0.943.

The total scores that students received from the scale were found to range between 36 and 108. The low total score that students received from the scale indicates a high level of CT skills (G*ü*lbahar et al., 2019). The reason for this inverse relationship was that those with high CT skills were directed to mark low scores on the Scale. CTS was administered to all students who participated in the study, including pre-test and post-test. Cronbach's Alpha reliability coefficient, calculated with the data from the research group, is 0.91.

Positive affect scale

The Positive Affect Scale section of the 'Positive and Negative Affect Schedule (PANAS) Scale' developed by Watson et al. (1988) was used. This scale was used to find out the positive effects of robotic coding teaching, designed according to the PBL approach, on students. Ten items of PANAS (sample items: interested, excited, enthusiastic), consisting of 20 items, measure positive affect. The remaining 10 items measure negative affect. The lowest score that can be obtained from the 5-point Likert type scale is 1 and the highest score is 50. A high score from the positive items of the scale indicates positive affects, while high scores from negative items indicate negative affects. Separate scores can be obtained for each factor from the scale, or the total score can be used. Only the positive affect scale was used in the study, because the negative affect scale contains items that are not suitable for the use of the study (e.g. distressed, upset, guilty, scared, hostile, jittery, ashamed, nervous, irritable, afraid). Since a structured learning environment for educational purposes was created in the study, it was not convenient to include negative affects.

Cronbach's Alpha analysis found that the positive emotion reliability coefficient of the scale was 0.83 (Gençöz, 2000). The positive affect scale was applied to students in the experimental group as a pre-test and post-test for each of the PBL scenarios. Cronbach's Alpha reliability coefficient, calculated for positive affect in the study, is 0.86 for scenario 1, 0.90 for scenario 2, 0.88 for scenario 3, 0.93 for scenario 4, and 0.92 for scenario 5.

Procedures

The activities performed during the robotics teaching are described in two sections: 'preparation before robotics teaching' and 'robotics teaching'.

Preparation before robotics teaching

Preparation of PBL scenarios. Special attention was paid to the fact that the PBL scenarios developed by the researcher are appropriate to students' level to help them achieve the outcomes of the 'Programming' topic in the 'Problem Solving and Programming' unit. The relationship between the prepared PBL scenarios and outcomes is presented in Table 2.

Table 2
Relationship between PBL Scenarios and Outcomes

Course Outcomes of the Applied Robotics Coding Training	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
1. Can recognize the interface and features of the block-based programming tool.	x				
2. Can create the correct algorithm to achieve the goals in the block-based programming environment.	x	x	x	x	x
3. Can explain the structure of linear logic.	x		x	x	
4. Can develop algorithms using linear logic structure.	x		x	x	
5. Can explain decision structure and functions.		x		x	x
6. Can develop algorithms involving decision structures.		x		x	x
7. Can explain loop structure and functions.		x	x	x	x
8. Can create algorithms containing loop structure.		x	x	x	x
9. Can debug by predicting the result of algorithms created for different structures.			x		

During the preparation stage of the PBL scenarios, real-life problems were presented for each scenario to arouse students' curiosity and facilitate their motivation. Then, expressions that encourage and guide students to solve the problem situation were included. In addition, visuals were added to the scenarios to make them more interesting and motivating. The prepared PBL scenarios were examined by three field experts (faculty members holding a doctoral degree in Computer Education and Instructional Technology (CEIT)) to determine their eligibility for the PBL approach and targeted outcomes. In line with the opinions of field experts, necessary revisions were made, and scenarios have been made ready for the robotics teaching.

Procedure before the robotics teaching is presented in Table 3.

Table 3
Procedure before the Robotics Teaching

Weeks	Activities Performed
1st Week	Identification of outcomes
2nd Week	Preparation of PBL scenarios
3rd Week	Receiving expert opinions for PBL scenarios and making necessary revisions
4th Week	Development of Draft Coding Skills Test
5th Week	Receiving experts' opinion for the coding skills test and making necessary revisions

Weeks	Activities Performed
6th Week	Piloting the Coding Skills Test
7th Week	Analysis of Coding Skills Test

Robotics teaching. It's hard to know what features of the treatment might account for any apparent benefits. For this reason, the robotics teaching process had been planned meticulously. The treatment was conducted on fifth-grade students. Students had received no instruction on robotic coding before. Thus, it was thought that students would not have prejudice against the course and the teacher. The same teacher was included in the experimental and control groups. Efforts were made to prevent possible teacher differences. Information was provided to ensure that the teacher was not susceptible to the control or experimental group. The experimental and control groups had previously been taught PBL-focused lessons in both classes. Thus, an attempt had been made to prevent possible situations that may arise from the novelty of the PBL environment and mislead the research data.

During the treatment, all students in the experimental and control groups were taught robotic coding, and mBlock block-based coding software and mBot robot Kit were used. The researcher carried out the robotic coding training and data collection process during the treatment. The process steps were:

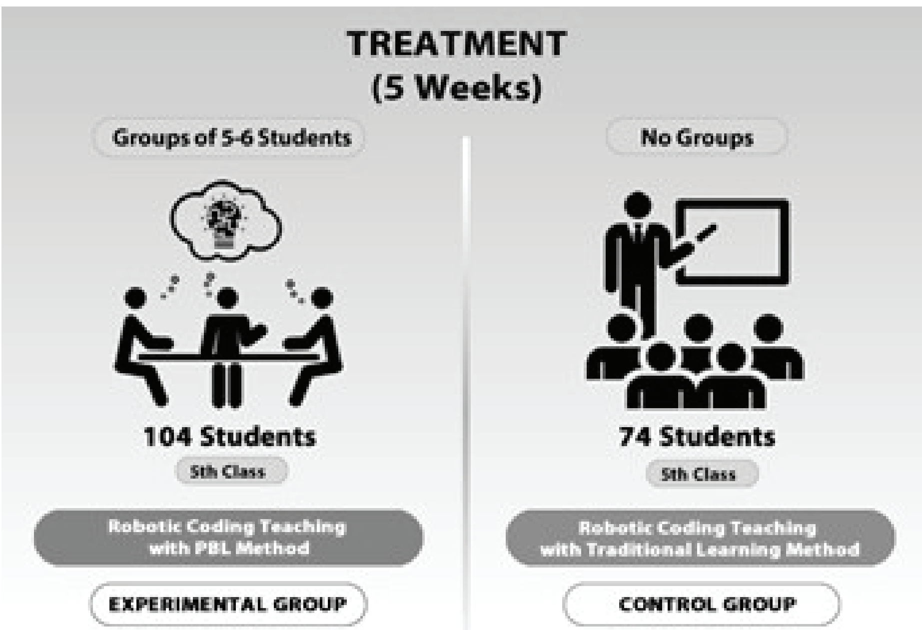

Figure 3. Figurative representation of the treatment process

1 The teaching of robotic coding was carried out in the experimental group through problem scenarios developed by the researcher, and traditional teaching methods were used in the control group. The robotics teaching lasted 5 weeks and consisted of 10 lessons. The treatment process is shown in Figure 3.

2 Training for both experimental and control groups was conducted in the same IT class, and the class had been prepared in terms of software and hardware resources before this training.

3 Before starting the treatment, students in the experimental group were given information about the PBL approach, and they were also shown some sample problem scenarios.

4 Students in the experimental group were divided into groups of five or six people. Groups were mixed in terms of gender, ability, success, social and personality characteristics. For this purpose, the observations of the researcher, who was also an IT teacher in the same school where the study was being conducted, were considered.

5 The positive affect scale was applied to the students in the experimental group before and after each PBL scenario during the treatment.

6 The treatment continued for seven weeks, including pre-testing and post-testing for all students.

The experimental group. The experimental group was taught through PBL scenarios prepared by the teacher/researcher based on the PBL approach. The researcher is the teacher of the relevant course. During the five weeks of robotics teaching when the teaching continued, the teacher/researcher distributed the scenarios to each student, one scenario each week at the beginning of the course, after announcing the targeted outcomes. In this way, students who had experienced unstructured problem situations noticed the problem in the scenarios, used the Internet resources to produce their solutions, and then wrote them in the relevant part of the scenario. As students found their solutions, they communicated with their teachers or teammates at any time and shared any topics they had just found with each other. Each student then agreed on a shared solution by discussing the solutions in their own groups and then wrote their solutions in the relevant part of the scenario on behalf of their group. Each group presented its solutions to the other students in the class. Finally, the teacher/researcher evaluated the results, and the final solution to the problem was achieved.

The teacher/researcher provided reflections about learning in the experimental group while guiding the process and students. In this direction, the researcher/teacher asked students questions in line with PBL scenarios (Appendix 1. A scenario used in teaching robotics) and encouraged students to research, ask questions and make relevant decisions. However, the teacher/researcher did not respond directly to the questions asked, encouraging students to find the right answer. The researcher/teacher helped create group dynamics motivating students and giving feedback about their learning, sometimes participating in students' activities. The experimental group is shown in Figure 4.

Figure 4. The experimental group: Teaching of robotic coding with PBL method

The control group. In the control group, the courses were taught using traditional teaching methods. Traditional learning is a form of practice in which methods such as lecture, question-answer and discussion are used under the leadership of the teacher. The traditional teaching method is a teacher-centered method in which the teacher determines the flow of the lesson, and decides on how the students will be guided and how the assessment will be carried out. The student is a passive receiver and imitator, so the way to learn is through good imitation of the teacher. In this way, a traditional learning approach was adopted in the control group.

Figure 5. Control group: Teaching of robotic coding with the traditional learning method

During the five weeks of robotics teaching, the teacher/researcher explained the relevant topic to the students at the beginning of the course, through pure narration and question and answer methods after announcing the targeted outcomes. Students could then participate in the course by demonstrating how to do it and allowing them to do it. Finally, the course ended by summarizing the topic after an in-class discussion.

In the control group, the teacher/researcher played a role in presenting the course content, managing discussions, asking questions, and responding directly to students' questions. However, the researcher/teacher also gave feedback about their learning by motivating students. The control group is shown in Figure 5.

The situations examined in the research were measured weekly. One reason for this is the way scales were used. The other and main issue is that emotional states and opinions about events may change weekly. The treatment process is presented in Table 4.

Table 4
Treatment Process

Weeks	Activities Performed
1st Week	Administering pre-tests (Coding Skills Test and CTS)
2nd Week	Pre-testing of experimental group's Positive Affect Scale Experimental Group - Robotic Coding with PBL Scenario 1 Post-testing of experimental group's Positive Affect Scale Control Group - Robotic Coding 1 with the traditional method
3rd Week	Pre-testing of experimental group's Positive Affect Scale Experimental group - Robotic Coding with PBL Scenario 2 Post-testing of experimental group's Positive Affect Scale Control Group - Robotic Coding 2 with the traditional method
4th Week	Pre-testing of experimental group's Positive Affect Scale Experimental group - Robotic Coding with PBL Scenario 3 Post-testing of experimental group's Positive Affect Scale Control Group - Robotic Coding 3 with the traditional method
5th Week	Pre-testing of experimental group's Positive Affect Scale Experimental group - Robotic Coding with PBL Scenario 4 Post-testing of experimental group's Positive Affect Scale Control Group - Robotic Coding 4 with the traditional method
6th Week	Pre-testing of experimental group's Positive Affect Scale Experimental group - Robotic Coding with PBL Scenario 5 Post-testing of experimental group's Positive Affect Scale Control group - Robotic Coding 5 with the traditional method
7th Week	Administering post-tests (Coding Skills Test and CTS)

Data analysis

The Kolmogorov-Smirnov test was used to test if the data obtained in the study had a normal distribution. As found with the normality tests, paired-samples t-test from parametric tests for normally distributed data, the Mann-Whitney U test from non-parametric tests for between-group data not normally distributed, and Wilcoxon test from non-parametric tests for within-group data not normally distributed were used. In addition, ANCOVA analysis was performed to determine the true effect of the experimental process by statistically checking other variables related to the dependent variable, other than the independent variable whose effect was tested in the study (Büyüköztürk, 2004). All statistical analyses were based on a 0.05 significance level. When there is a significant difference in the calculated results, the value of eta-square (η^2) effect size was calculated and interpreted as follows; small if it is 0.01-0.06, medium if it is 0.06-0.14, high if it is 0.14 and above (Cohen, 1988).

Results

Results regarding the impact of the PBL approach on coding skills

To examine the effect of robotic coding designed according to the PBL approach on the coding skills of secondary school students, intra-group and inter-group coding skills of experimental and control groups' pre-test - post-test scores were compared. Within group coding skills of experimental and control groups' pre-test - post-test scores were compared using a paired sample t-test (Table 5).

Table 5

Paired Sample t-Test Results for the within Group Coding Skills of Experimental and Control Groups' Pre-test - Post-test Scores

Group	Test	*n*	*x*	*t*	*p*	η^2
Experimental Group	Pre-Test	104	8.87	-13.212	0.000	0.352
	Post-Test	104	13.90			
Control Group	Pre-Test	74	9.12	-8.756	0.000	0.222
	Post-Test	74	12.65			

When Table 5 is examined, it is seen there are significant differences between the coding skills of both experimental and control group students' pre-test and post-test scores (p=0.000<0.05 for the experimental and control group). The differences were in favour of the post-test. When the average scores of both tests are examined, there is an increase in the coding skill scores of both the experimental and control group.

In comparing the coding skill scores of the experimental and control group between the groups, the coding skill pre-test scores of both groups were compared. Since both groups' coding skills pre-test scores did not have a normal distribution, the groups were compared with the Mann-Whitney U test.

When Table 6 is examined, it can be seen that there is no significant difference between the coding skills pre-test scores of experimental and control group students

(p=0.666>0.05). Accordingly, it could be claimed that preliminary knowledge of coding skills of the experimental and the control group is similar. Therefore, the coding skill post-test scores of both groups were compared. Since the coding skills in neither group had a normal distribution in the post-test data, the groups were compared with the Mann-Whitney U test.

Table 6
Results of the Mann-Whitney U Test on Intergroup Coding Skills Test Scores of Experimental and Control Groups

Test	Group	n	$\bar{X}$	Total Score	U	p	η^2
Pre-Test	Experimental	104	8.87	922	3702.50	0.666	
	Control	74	9.12	675			
Post-Test	Experimental	104	13.90	1446	3093.50	0.025	0.026
	Control	74	12.65	936			

When Table 6 is examined, it is seen that there is a significant difference between the coding skill of experimental and control group students' post-test scores (p=0.025<0.05). This difference was found in favour of the experimental group. In other words, the coding skill post-test scores of the experimental group ($\bar{X}$=13.90) are significantly higher than the coding skills post-test scores of the control group ($\bar{X}$=12.65).

Findings on the effect of the PBL approach on CT skills

To examine the effect of the teaching robotic coding designed according to the PBL approach on students' CT skills, within-group CTS pre-test - post-test scores and inter-group CTS scores of experimental and control groups were compared. Paired samples t-test were used to compare the pre-test and post-test CT skills of the experimental group. Since the data did not have a normal distribution, the Wilcoxon test was used to compare the control group's pre-test and post-test CT skills (Table 7).

Table 7
Test Results for within-Group CTS Pre-test – Post-test Scores of Experimental and Control Groups

Group		n	$\bar{X}$	Test	t	Z	p	η^2
Experimental Groups	Pre-Test	104	64.41	Paired Samples t-Test	12.270		0.000	0.174
	Post-Test	104	52.34					
Control group	Pre-Test	74	59.14	Wilcoxon Test		-5.432	0.000	0.055
	Post-Test	74	52.32					

When Table 7 is examined, it is seen that there are significant differences between the CTS pre-test and post-test scores of both experimental and control group students (p=0.000<0.05 for the experimental and control group). These differences were in favour of the post-test. When the average scores of both groups are examined, there is a decrease in CTS scores. The decrease in the total score that students obtained from the scale indicates that the level of CT skill increased (Gülbahar et al., 2019).

In comparing the CTS scores of the experimental and control groups, the CTS pre-test scores of both groups were compared first. Since the pre-test scores of the control group did not have a normal distribution, the Mann-Whitney U test was used to compare the pre-test scores of both groups (Table 8).

Table 8
Mann-Whitney U Test Results of CTS Pre-test Scores

Group	*n*	$\bar{X}$	Total Score	*U*	*p*	η^2
Experimental	104	64.41	6699	2832.50	0.003	0.033
Control	74	59.14	4376			

When Table 8 is examined, it is seen that there is a significant difference between the CTS pre-test scores of experimental and control group students ($p=0.003<0.05$). It was found that this difference was in favour of the students in the control group.

ANCOVA analysis was used to compare the CTS scores of the experimental and control groups, as there was a significant difference between the CTS pre-test scores of the experimental and control groups. In this context, the CTS pre-test scores of the experimental and control groups were taken as control variables, and the adjusted post-test scores of the groups were compared. Table 9 presents descriptive statistics for the groups' pre-test, post-test, and adjusted post-test CTS scores.

Table 9
CTS Pre-test – Post-test Score Averages of Experimental and Control Groups, Standard Deviations and Adjusted Post-test Score Averages

		Pre-Test Score Averages		Post-Test Score Averages		Adjusted Post-Test Score Averages	
Group	*n*	$\bar{X}$	*Ss*	$\bar{X}$	*Ss*	$\bar{X}$	*Ss*
Experimental	104	64.41	12.91	52.34	13.51	50.84	0.87
Control	74	59.14	15.77	52.32	12.50	54.43	1.04

The ANCOVA analysis result, in which the CTS adjusted post-test scores of the experimental and control groups are compared in Table 10.

Table 10
ANCOVA Analysis Results on CTS Adjusted Post-Test Scores of Experimental and Control Groups

Source of Variance	Sum of Squares	*Sd*	Mean of Square	*F*	*p*	η^2
Adjusted Model	16510.475	2	8255.238	105.504	0.000	0.547
Pre-Test	16510.469	1	16510.469	211.008	0.000	0.547
Group	540.543	1	540.543	6.908	0.009	0.038
Error	13692.968	175	78.246			
Adjusted Total	30203.444	177				

When Table 10 is examined, it is seen that there is a statistically significant difference between the CTS scores of the experimental and control group students when the pre-test scores are controlled (p=0.009<0.05). There is a difference between the CTS scores of the groups in favour of the experimental group, regardless of the pre-test scores.

Findings on the effect of the PBL approach on positive affect states

For each PBL scenario, the Wilcoxon test was used to compare positive affect pre-test – post-test scores as the data did not have normal distribution characteristics (Table 11).

Table 11
Descriptive Statistics and Normal Distribution Test Results of Positive Affect Pre-Test – Post-Test Scores of the Experimental Group and Wilcoxon Test Results

Scenarios		*n*	$\overline{X}$	Paired Samples Test Type	*p*	η^2
Scenario 1	Pre-Test	104	35.83	Wilcoxon Test	0.000	0.060
	Post-Test	104	39.57			
Scenario 2	Pre-Test	104	32.58	Wilcoxon Test	0.000	0.091
	Post-Test	104	38.71			
Scenario 3	Pre-Test	104	35.67	Wilcoxon Test	0.000	0.021
	Post-Test	104	38.38			
Scenario 4	Pre-Test	104	34.01	Wilcoxon Test	0.000	0.047
	Post-Test	104	38.63			
Scenario 5	Pre-Test	104	38.63	Wilcoxon Test	0.000	0.018
	Post-Test	104	41.44			

When Table 11 is examined, it is seen that, for each PBL scenario, there are significant differences between the positive affect pre-test and post-test scores of the experimental group students (p=0.000<0.05). These differences were in favour of post-test data. In other words, the positive affect scores of the experimental group increased significantly in each of the PBL scenarios.

Discussion

When the results of coding skills were examined, it was observed that the coding skills of both experimental and control groups increased significantly at the end of the treatment. However, the coding skills of the experimental group students were significantly more developed than those of the control group students. In other words, it was found that the teaching of robotic coding designed according to the PBL approach had a positive effect on students' coding skills. Teachers need well-planned roadmaps to guide them in integrating CT into their instructional processes (Israel-Fishelson et al., 2021; Lockwood & Mooney, 2017). Research results have shown that students' CT-related skills improve if this need can be met. The research is also valuable because it offers planning that will guide teachers in acquiring CT skills in coding lessons. However, in the relevant literature, there are very few examples of teacher plans for teaching robotic coding designed according to the PBL approach. Lykke et al. (2014) conducted experimental research and applied PBL design and found that students noted that robots effectively develop coding skills and students' motivation. This research supports the conclusion that teaching robotic coding, designed according to the PBL approach used in the study, increases students' coding skills.

When the findings related to CT skills were examined, it was seen that the CT skill levels of both the experimental and control group increased significantly at the end of the treatment. The findings of the research claiming that using robots in the teaching of coding increases students' CT skills (Baek et al., 2019; Bers et al., 2019; Chalmers, 2018; Constantinou & Ioannou, 2018; Luo et al., 2020; Roussou & Rangoussi, 2020; Stewart et al., 2021; Sullivan et al., 2017; Wu & Su, 2021) and the findings of this research support each other. In addition, the CT skills of the students in the experimental group were significantly more developed than those of the students in the control group. In other words, it was found that the teaching of robotic coding designed according to the PBL approach had a positive effect on students' CT skills. The relationship of CT to the outcomes of well-planned coding practices (Garcia-Penalvo & Mendes, 2018) is also confirmed with this study. The findings of the research claiming that arranging problem-solution activities in the robotics curriculum based on their nature improved students' CT skills (Angeli & Valanides, 2019; Caballero-Gonzalez et al., 2019; Chen et al., 2017; Kale & Yuan, 2021) and have also supported the findings of this research. It is also known that CT helps develop problem-solving skills (Grover & Pea, 2013; Wing, 2008). With this study, it was found that developing problem-solving skills also improved CT. What is surprising for the researcher is that the relationship between CT and problem-solving skills may be bidirectional.

When the positive affect-related findings were examined, it was observed that each of the problem scenarios given to the experimental group according to the PBL approach during the research process significantly increased the positive affect of the students. It could also be claimed that awaking positive affects of students will increase their success (Konradt et al., 2003; Lyubomirsky et al., 2005; Pekrun et al., 2002). Haapasalo and Samuels (2011), on the other hand, argued that the enjoyment felt through robotics in mathematics education can increase students' motivation to learn. Achieving motivation is associated with positive affects (Pekrun et al., 2002). Stewart et al. (2021) also claimed that motivated students could demonstrate better problem-solving skills. Similarly, Ersoy et al. (2011) stated that using robots in the teaching of coding increases motivation in the lesson, creating long-lasting and more meaningful learning. The fact that the coding skills and CT skills of the experimental group students who were taught robotic coding with the PBL approach in the study were significantly more developed than those of the control group students who were taught using the traditional learning approach supports the research in the relevant literature.

Within the scope of all the results obtained with this study, robotic coding teaching designed according to the PBL approach contributes to the literature in the context of coding skills, CT, problem-solving skills and positive affect relationship network.

Conclusion

CT skill is a very difficult skill to evaluate due to its complex nature, which includes many processes such as critical, creative and algorithmic thinking, problem-solving, communication skills, and collaborative work (G*ü*lbahar et al., 2019; Yeni, 2017). The big picture of the research is summarized in Figure 6.

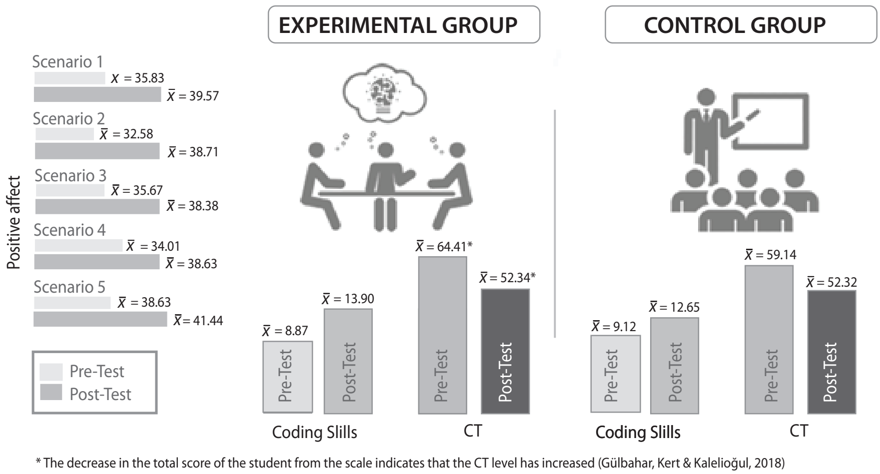

Figure 6. Conclusions obtained based on research findings

At the end of the treatment, the coding skills of both experimental and control groups were found to have significantly increased. In other words, it was found that the educational robot kits used in both groups affect coding skills positively. The coding skills of the experimental group students were significantly higher than those of the control group students. In other words, it was found that the teaching of robotic coding designed according to the PBL approach had a positive effect on students' coding skills.

At the end of the treatment, CT skill levels of both the experimental and control groups increased significantly. In other words, it was found that using educational robot kits in the teaching of coding has a positive effect on CT skill. CT skills of the students in the experimental group were significantly higher than those of the control group's CT skills. In other words, the research revealed that CT skills could be improved through a curriculum organized with a PBL approach.

During the treatment, each of the problem scenarios given to the experimental group according to the PBL approach was found to have significantly increased the positive affects of the students. It could be claimed that activating positive affects of students will be effective in increasing their achievement. In the study, the fact that the coding and CT skills of experimental group students who received teaching of robotic coding through the PBL approach were significantly higher than those of the control group students who received teaching of robotic coding through the traditional learning approach supports this finding.

In the research, the curriculum was organized with the PBL approach. Thus, there was an attempt to activate CT skills. Coding environments could be created where instructional programs are organized within different bases. By making curriculum arrangements with different approaches, their effects on CT skills could be examined. Thus, the ways to achieve these skills could be explored. In the future, similar research could be conducted on the students of different ages, and different variables such as problem-solving, creative thinking and critical thinking ability, motivation, attitude could be examined. Different robot kits and different coding environments could be used, and the obtained results could be compared. In the study, the effect of the teaching of robotic coding designed according to the PBL approach on students' CT skills was evaluated based on the total score of CTS's sub-factors. In future studies to be conducted, five sub-factors could be examined individually. Control group students were taught robotic coding by the traditional method, while each student could not be given a robot kit individually due to the excessive-class size and cost-related factors. Therefore, students had to perform their coding with seven robot kits. In the studies to be conducted in the future, this gap could be corrected and the obtained results could be compared. On the other hand, studies can be designed to examine the efficient number of the group members using robotic kits. In addition, the coding skills of the students in the study were measured by developing a standard achievement test due to the insufficient number of mBot robot kits used. Practical tests could measure the coding skills of students.

Limitations

The research process was planned in detail. It took approximately 6 months to prepare the teaching plans and materials. In this process, an attempt was made to visualize the pre-experimental process and the moment of the experimental process, and possible limitations were avoided. However, the research still has some limitations. Researchers discussed the following two limitations among themselves:

1. Did PBL make the difference, or did peer-focused group work make the difference?
2. Did PBL make a difference, or did giving experimental group students more autonomy make the difference? These questions need to be considered in other research.

Another limitation is that the research examined students' self-efficacy perceptions regarding their CT skills, not their CT skill level.

In addition, another limitation of the study is that only the experimental group was measured for positive affect. In the study, it was not examined which of the experimental and control groups has a higher positive affect; it was investigated whether problem-based learning scenarios would activate students' positive affects. In other studies, the positive affect states of the experimental and control groups can also be compared.

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Appendix 1
Example of a scenario

mBot Solution to Power Outages

Orkun spends his summer vacations in the village with his grandfather. While Orkun is there, he helps his grandfather with some work. In the evenings he reads books. However, there are frequent power cuts in the village. Grandfather and Orkun remain in the dark. Orkun thinks that he can solve this problem with the robotic coding they learned in the information technologies course. He develops a project and tells his grandfather about it.

Orkun: Grandpa, I decided to design a robot that will save us from darkness when there is a power cut. I will use the mBot kit for this. mBot will automatically light up when the power is cut and the environment gets dark. It will turn off when the power comes back on and the environment brightens.

Grandfather: That's a great idea Orkun! This robot will help us a lot when the power goes out. It will save us from the darkness when the power goes out. But how are you going to do it?

Orkun: …..

Poučavanje robotike putem problemskoga učenja za poboljšanje vještina računalnoga razmišljanja, vještina kodiranja i pozitivnih afekata

Sažetak

Ovim se istraživanjem željelo ispitati učinak poučavanja robotskoga kodiranja osmišljenoga prema pristupu problemskoga učenja (PBL) za učenike starijih razreda osnovnih škola (u dobi od 11 do 12 godina) na njihove vještine kodiranja, vještine računalnoga razmišljanja (CT) i pozitivnih afektaa. U istraživanju je korišten model „polueksperimentalnoga dizajna s predtestom i posttestom s kontrolnom skupinom", a istraživačku je skupinu činilo 178 učenika 5. razreda osnovnih škola. Tijekom istraživačkoga procesa, 104 učenika u eksperimentalnoj skupini učilo je „robotsko kodiranje metodom problemskoga učenja", dok je 74 učenika u kontrolnoj skupini učilo „robotsko kodiranje tradicionalnom metodom" tijekom pet tjedana. Prema dobivenim rezultatima uočeno je da su se vještine kodiranja i vještine računalnoga razmišljanja i u eksperimentalnoj i u kontrolnoj skupini značajno povećale. Međutim, vještine kodiranja i CT vještine učenika iz eksperimentalne skupine bile su znatno veće od onih u kontrolnoj skupini. Osim toga, tijekom tretmana, svaki od problemskih scenarija zadanih eksperimentalnoj skupini prema PBL pristupu značajno je povećao pozitivne afekte učenika. Kao rezultat rasprave o literaturi i istraživačkim nalazima, smatra se da PBL i CT vještine mogu djelovati dvosmjerno. Ovu bi tvrdnju valjalo dodatno istražiti.

Ključne riječi: *vještine kodiranja; računalno razmišljanje; obrazovna robotika; pozitivan afekt; problemsko učenje; rješavanje problema; robotsko kodiranje*

Uvod

U 21. stoljeću, kada je pristup digitalnim okružjima tako jednostavan, koje vještine učenici mogu steći kako bi se bolje pripremili za budućnost? Drugim riječima, koje bi im vještine u njihovom rješavanju životnih problema pomoću tehnologije mogle pružiti priliku za razvoj? S brzom tranzicijom u digitalni život, akademici i edukatori potaknuli su nas da se usredotočimo na to koje će vještine „rastuće generacije" trebati u budućnosti (Lockwood i Mooney, 2017; Sonnleitner i sur., 2014). U izvješću Organizacije za ekonomsku suradnju i razvoj (OECD) koje su pripremili Ananiadou i Claro (2009), neke vještine navedene su kao karakteristike učenika. Za njih se očekivalo da ih učenici pokažu kao vještine, a ne kao znanje koje treba posjedovati, poput kreativnosti, kritičkoga mišljenja i rješavanja problema (Bocconi i sur., 2016). Sve je veća potreba za rješavanjem složenih problema (Sonnleitner i sur., 2014). Fokus se stavlja na pitanje kako „steći" te vještine koje učenici trebaju pokazati u svojem životu (Kafai i Burke, 2013; Seow i sur., 2019; Sonnleitner i sur., 2014). Zatim su predstavljene neke vještine pismenosti koje se očekuju od budućih građana na Svjetskom ekonomskom forumu, uključujući računalno razmišljanje (CT) (Svjetski ekonomski forum, 2015). Svi ti događaji imali su značenje: trebalo je dodati CT u osnovne vještine učenika, kao što su čitanje, pisanje i matematika (Wing, 2006).

Wing (2006) je definirao CT kao „rješavanje problema, dizajniranje sustava i razumijevanje ljudskoga ponašanja, oslanjajući se na koncepte temeljne za računalne znanosti (CS)". Wing (2011) je kasnije revidirao svoju definiciju, tvrdeći: „CT su procesi razmišljanja uključeni u formuliranje problema i njihovih rješenja tako da se rješenja prikazuju u obliku koji može učinkovito provesti agent za obradu informacija." CT je sposobnost korištenja algoritamskih metoda za prepoznavanje i rješavanje problema, usredotočujući se na stvarne probleme u svijetu (Shute i sur., 2017). CT vještine i tehnike razmišljanja pomažu u razvoju vještina rješavanja problema (Grover i Pea, 2013; Wing, 2008). Wing (2006) naglašava da se CT može koristiti u mnogim područjima svakodnevnoga života i da bi se trebao poučavati učenicima u mlađoj dobi. Kada se promatra napredak od tada do danas, primjećuje se da je CS obuka postala popularnija, ali da se obuka CT-a na svjetskoj razini još uvijek nalazi u početnoj fazi, posebno kada se razmatra faza integracije u K-12 obrazovanje (Lockwood i Mooney, 2017).

CT je temeljna vještina za učenike (Zhong i sur, 2016), a CS je prvi put uključen u K-12 kurikule diljem svijeta kako bi se učenicima omogućilo stjecanje te vještine (Balanskat i Engelhardt, 2015; Brown i sur., 2013). CS je integriran u kurikul putem projekata u Sjedinjenim Državama (CSTA, 2011), Tajvanu (NAER, 2018), Australiji (Australian Curriculum, Assessment, Reporting Authority, 2013) i Turskoj (FATİH, 2012). Nacionalna zaklada za znanost (NSF) u Sjedinjenim Državama izdvojila je 120 milijuna dolara za integraciju CS-a u kurikul (Kale i sur., 2018).

Pokret za poboljšanje mogućnosti i unaprjeđenje tehnologije (FATİH projekt), započet 2010. godine u Turskoj, je sveobuhvatni obrazovni pokret koji ima za cilj poboljšati pristup alatima informacijske tehnologije (IT) u školama. FATİH projekt je višedimenzionalni projekt koji ima za cilj pružiti IT hardver, softver, infrastrukturu mreže i pristup internetu svim školama te razviti e-sadržaje (MEB, 2021). U skladu s tim ciljevima, naziv kolegija Informacijske tehnologije ažuriran je 2012. godine kao Informacijske tehnologije i softver. Kao što su Kafai i Burke (2013) tvrdili, ova iskustva otkrivaju da se poučavanje programiranja vratilo u kurikule u školama nakon osamdesetih godina prošloga stoljeća. Međutim, ovdje vrijedi napomenuti da je ovo vraćanje uvedeno s nekim razlikama. Prva značajna razlika bila je da je „CT temeljna vještina za sve, a ne samo za računalne znanstvenike“ (Wing, 2006). Drugim riječima, trenutačna CS obuka nije složenost o kojoj bi učenici trebali učiti programiranje „kao cilj“ (Wu i Su, 2021). To je struktura blokova kroz koju učenici mogu stvarati proizvode programiranjem, rješavati probleme koristeći ih „kao alate“ (Garcia-Penalvo i Mendes, 2018). Postoji stalna tendencija prema uključivanju CT-a umjesto CS-a u K-12 kurikul (Tran, 2019). CT se odnosi na kognitivni proces rješavanja problema (Wing, 2008). Kodiranje je jedan od ključnih načina za postizanje CT-a (Wu i Su, 2021). Stoga se izraz „kodiranje“ preferira u odnosu na programiranje. Očekuje se da učenici budu proizvođači u ovom procesu kako bi rješavali probleme iz stvarnoga života (Garcia-Penalvo i Mendes, 2018). Posljednja je razlika da oni doživljavaju konkretan CT proces kroz koji proizvode, rješavaju probleme i otklanjaju greške (poput promatranja neželjenih pokreta robota) (Wing, 2011). U tom su procesu fizički tečajevi robotike integrirani u osnovno obrazovanje (iako to može ovisiti o zemlji, počevši od dobi od 10 do 11 godina) (Wu i Su, 2021). Kada pogledamo odraz ovoga na praksu u Turskoj, vidimo da je sadržaj kolegija Informacijske tehnologije i softver ažuriran 2018. godine dodavanjem poučavanja kodiranja (TTKB, 2018).

CT nije samo pitanje kodiranja, već je povezan s ishodima dobro planiranih praksi kodiranja (Garcia-Penalvo i Mendes, 2018). Učitelji također trebaju dobro planirane primjere kodiranja kako bi integrirali CT u svoj obrazovni sadržaj (Israel-Fishelson i sur., 2021; Lockwood i Mooney, 2017). Ti dobro planirani primjeri kodiranja znače korištenje metoda koje mogu simulirati jednostavne svakodnevne probleme povezane sa životom (Wu i Su, 2021). Problemsko učenje (PBL) moglo bi biti jedna metoda za simulaciju ove situacije. U relevantnoj literaturi postoji nekoliko studija koje se odnose na poučavanje robotskoga kodiranja temeljeno na PBL pristupu. Kao dio ovoga istraživanja, izrađene su detaljne nastavne priprave korištenjem PBL metode za poboljšanje CT vještina učenika srednjih škola. Ove se priprave promatraju kao resursi od kojih učitelji mogu imati koristi. Osim toga, ove priprave pripremljene na temelju PBL metode primjenjive su, a CT vještine učenika, stanja, pozitivan afekt i vještine kodiranja testirane su eksperimentalnom metodom.

Cilj

Ovo istraživanje ima za cilj otkriti učinak poučavanja robotskoga kodiranja osmišljenog aprema PBL pristupu na vještine kodiranja, CT vještine i pozitivan afekt učenika u srednjim školama.

Za navedeni cilj traženi su odgovori na sljedeća istraživačka pitanja:

1. → Kakav je učinak poučavanja robotskoga kodiranja osmišljenoga u skladu s PBL pristupom

na vještine kodiranja?

2. → Kakav je učinak poučavanja robotskoga kodiranja osmišljenoga u skladu s PBL pristupom na CT vještine?

3. → Kako se mijenja pozitivni afekt učenika u svezi s problemskim scenarijima u poučavanju robotskoga kodiranja osmišljenoga u skladu s PBL pristupom?

Pregled literature

Kodiranje s robotikom i računalno razmišljanje

Suradnja s umjetnom inteligencijom i pametnim tehnologijama u životnim i radnim okružjima dovela je do promjena u vještinama koje se očekuju od pojedinaca. Međunarodno društvo za tehnologiju u obrazovanju (ISTE) službeno je objavilo da se od učenika očekuju vještine računalnoga razmišljanja (CT) od 2016. godine (ISTE, 2016). CT ističe vještine kodiranja u CS tečajevima (Kale i sur., 2018). CT je mnogo više od kodiranja, ali je kodiranje važan alat koji može osigurati razvoj CT vještina (Voogt i sur., 2015). Kodiranje pomaže pojedincima steći vještine višega reda razmišljanja, poput rješavanja problema, kreativnoga razmišljanja i suradničkoga rada, više nego samo učenje pisanja koda (Fessakis i sur., 2013).

U poučavanju kodiranja mnogi koncepti i procesi ostaju apstraktni za učenike, a učenici imaju poteškoća u konkretizaciji informacija. U tom se trenutku u literaturi pojavljuje poučavanje robotskoga kodiranja, pri čemu se mehanika i kodiranje koriste zajedno. Korištenje robota u poučavanju kodiranja konkretizira pojmove povezane s kodiranjem i povećava vještine kodiranja učenika čineći proces zabavnijim i zanimljivijim (Çankaya i sur., 2017; Martin-Ramos i sur., 2018; Özdemir i sur., 2009; Soykan, 2018; Şimşek, 2018; Xia i Zhong, 2018), poboljšava njihove vještine rješavanja problema i kritičkoga razmišljanja (Merlo-Espino i sur., 2017; Sung i sur., 2017) te povećava njihov školski uspjeh i percepciju samoučinkovitosti (Kasalak, 2017).

Danas je korištenje softvera za robotsko kodiranje te fizičkih i virtualnih okružja za kodiranje robota vrlo popularno. mBlock, koji je proizvela Makeblock kompanija, sastoji se od Scratch 2.0 i 3.0 robotskih i Arduino platformi, koje omogućuju grafičko vizualno kodiranje. Trenutačna verzija, koja podržava gotovo 20 jezika, također je kompatibilna s različitim operativnim sustavima (Makeblock, 2019). Snimka zaslona mBlock vizualnoga okružja za kodiranje temeljeno na blokovima i mBot robota prikazana je na Slici 1.

Slika 1

Robotika i kodiranje vode pojedince prema računalnom razmišljanju (CT), obuhvaćajući procese rješavanja problema (Lye i Koh, 2014). CT ne bi trebalo smatrati samo vještinom rješavanja problema. Wing (2008) tvrdi da CT ne bi trebao biti novo ime za proces rješavanja problema, već da CT također uključuje različite procese poput kritičkoga razmišljanja, algoritamskoga razmišljanja i apstrakcije, kao i rješavanja problema.

Kodiranje je način poticanja CT-a. Logika koja stoji iza korištenja kodiranja i robotike za poboljšanje CT vještina naglašava različite CT komponente, kao što su analiza problema, apstrakcija, generalizacija i ispravljanje grešaka (Shute i sur., 2017). Proces kodiranja omogućuje pojedincima da naprave više pokušaja i koriste različite elemente problema kako bi razvili, testirali i poboljšali rješenja za zahtjevne zadatke te pruža priliku za primjenu CT vještina (Kale i Yuan, 2021). Mnoge studije pokazuju da obrazovanje pozitivno utječe na CT vještine (Akçay i sur., 2019; Alsancak Sirakaya, 2018; Erdem, 2018; Garneli i Chorianopoulos, 2019; Zhaoa i Shute, 2019), a učenici su ovaj proces smatrali zabavnim i zanimljivim.

Međutim, kombiniranje obuke kodiranja s robotikom, koja se fokusira na vještine rješavanja problema kako bi pripremila učenike za njihove buduće karijere, omogućuje učenicima da konkretno prate svoje misli. Učenici koriste svoje kognitivne vještine pri pisanju koda i identificiraju svoje pogreške u razmišljanju prateći pokrete svojih robota. Obrazovna robotika nedavno se koristila za brojne obrazovne ciljeve, uključujući poboljšanje CT vještina (Stewart i sur., 2021). Osim toga, robotika je interdisciplinarni način za integraciju i primjenu CT-a (Shoop i sur., 2016). Korištenje robota u poučavanju kodiranja povećava CT vještine učenika (npr. Baek i sur., 2019; Bers i sur., 2019; Chalmers, 2018; Constantinou i Ioannou, 2018; Luo i sur., 2020; Roussou i Rangoussi, 2020; Sullivan i sur., 2017). Ove studije pokazuju da učitelji mogu koristiti robotiku u kurikulu počevši od osnovne škole kako bi poboljšali CT vještine učenika (Stewart i sur., 2021). Skriptirani, organizirani i planirani kurikuli i prakse potrebni su za razvoj CT vještina (Cutumisu i Guo, 2019; Kale i sur., 2018).

Od 2017. godine provodi se sve veći broj istraživanja o robotskom kodiranju i CT-u. Primjećuje se da se većina ovih studija provodi na razini predškolskoga i osnovnoškolskoga obrazovanja. Ova studija, provedena s učenicima u prvim godinama srednje škole (11 – 12 godina), predstavlja rezultate primjena napravljenih za različite razine pronađene u literaturi.

Problemsko učenje i CT

Rješavanje problema osnovna je vještina koja stoji iza računalnoga razmišljanja (CT) i jedna je od najvažnijih (Van Merriënboer, 2013). Kako bi učitelji integrirali CT u svoje nastavne procese, moraju razumjeti prirodu rješavanja problema i CT (Kale i sur., 2018). Rješavanje problema obuhvaća „razumijevanje, planiranje i praćenje, izvršavanje i samoregulaciju" (Mayer i Wittrock, 2006). Priroda CT-a uključuje „suočavanje, dekompoziciju, prepoznavanje obrazaca, apstrakciju, algoritam i analizu" (Grover i Pea, 2013; Kale i sur., 2018). Kada se ispituju dostupne alternative u rješavanju problema, CT identificira karakteristike koje se ističu. Tijekom procesa rješavanja problema, provode se planirani koraci akcije. Sustav automatizacije koraka za rješavanje problema provodi se u CT-u. U rješavanju problema, kada se donose kontrole i odluke, u CT-u se provodi testiranje, ispravljanje pogrešaka i otklanjanje problema. Ove progresivne strukture i rješavanja problema i CT-a zahtijevaju dizajn nastavnih predmeta kroz skriptiranje nastavnih procesa u razvijanju CT vještina (Israel-Fishelson i sur., 2021; Lockwood i Mooney, 2017; Steward i sur., 2021). Primjerice, Chen i sur. (2017) organizirali su kurikul robotike kao „pisanje koda na komad papira, testiranje koda na virtualnom robotu, a zatim pokretanje testiranoga koda na fizičkom robotu".

Učenje temeljeno na problemima (PBL) je pedagoška strategija usmjerena na učenike koja im pruža smjernice i resurse, priliku da razmisle o svojem znanju i vještinama rješavanja problema te usporede to s nestrukturiranim problemima povezanim sa stvarnim životnim iskustvima (Hoffman i Ritchie, 1997). PBL podržava cjeloživotno učenje s ciljem da učenici nauče kako učiti. U PBL pristupu, problem se koristi za motivaciju učenika, odnosno za pokretanje i razvoj učenja stavljanjem problema u središte. Kurikul se može koristiti prilikom pisanja PBL scenarija. U tom procesu koncepti iz kurikula mogu se objasniti učenicima u skladu sa situacijom problema (Gallagher i sur., 1995).

Poznato je da predmeti dizajnirani s PBL pristupom povećavaju postignuća učenika (npr. Alper i Deryakulu, 2008; Gao i sur., 2019; Gürlen, 2011; Moralar, 2012; Şendağ, 2008). PBL pristup poznat je po tome što povećava kreativne vještine razmišljanja učenika (Yaman i Yalcin, 2005), vještine rješavanja problema (Denis i Hubert, 2001; Tseng i sur., 2008), emocionalnu inteligenciju (Caballero-Gonzalez i sur., 2019; Luy-Montejo, 2019), kritičke vještine razmišljanja (Saputra i sur., 2019; Sierra Rativa, 2019) i motivaciju (Ersoy i Baser, 2010; Lykke i sur., 2014). Chen i sur. (2017) primijenili su kurikul robotike razvijen na temelju rješavanja problema kroz šest mjeseci na razini osnovne škole. Otkrili su da su se CT vještine učenika poboljšale. Caballero-Gonzalez i sur. (2019) pripremili su nastavne pripreme koristeći aktivnosti rješavanja problema u svojem istraživanju. Koristili su edukativne robotske setove (Bee-Bot) u svojem istraživanju i otkrili da su učenici u osnovnoj školi poboljšali svoje socijalne interakcije i CT vještine. Slično tome, Angeli i Valanides (2019) proizveli su scenarije rješavanja problema u svojem istraživanju. Koristili su robotske setove (Bee-Bot) u svojim lekcijama koje su poučavali u skladu sa scenarijima. Ovim istraživanjem otkrili su da su se CT vještine učenika poboljšale. Kale i Yuan (2021) ispitali su nastavne priprave za kodiranje u trećem razredu osnovne škole na mrežnoj stranici code.org i utvrdili da su metode poučavanja rješavanja problema korištene za poboljšanje CT i vještina rješavanja problema te da su ti planovi lekcija podržavali ove vještine.

U ovom skriptiranom procesu kurikula, učitelji bi trebali dobro razumjeti prirodu rješavanja problema u CT-u (Voogt i sur., 2015) i predstaviti svoj nastavni sadržaj kroz scenarije problema (Kale i sur., 2018). Predstavljanje nastavnoga sadržaja kroz scenarije problema olakšat će posao učiteljima i podržati ciljeve učenja (Kale i sur., 2018, Lye i Koh, 2014). Potrebno je proizvesti i testirati takve dizajne tečajeva za razvoj CT vještina.

Pozitivni afekti i robotika

Pozitivni afekti poput zainteresiranosti, uzbuđenja, snage, entuzijazma, ponosa, inspiracije, odlučnosti, pažnje i aktivnosti čine ljude sretnima i pozitivno doprinose njihovom uspjehu (Lyubomirsky i sur., 2005). Oni također omogućuju osobi da razmišlja na različite načine, bude kreativnija i zabavnija, čineći je sigurnom bez osjećaja ugroženosti (Fredrickson, 1998, 2001).

Şişman i Küçük (2019), koji su ispitali percepcije i iskustva budućih učitelja na tečajevima obrazovne robotike, otkrili su da su uživanje i motivacija snažno povezani.

Haapasalo i Samuels (2011), s druge strane, tvrde da zabava kroz robotiku u obrazovanju matematike može povećati motivaciju učenika za učenje. Stewart i sur. (2021) također tvrde da će motivirani učenici pokazati bolje vještine u rješavanju problema. To znači da je potreban kontinuitet zadatka u razvoju vještina učenika u rješavanja problema učenika (Jõgi i Kikas, 2016), a učenici s većom motivacijom često su uporniji u izvršavanju dodijeljenoga zadatka (Hardre i Reeve, 2003). Kada se ispituju načini pristupa rezultatima koji zahtijevaju dugotrajne operacije poput motivacije, oni su povezani s pozitivnim afektima kao što su uživanje, nada i ponos (Pekrun i sur., 2002). Međutim, studije koje istražuju odnos između uživanja u učenju i motivacije tvrde da postoji pozitivan odnos između ove dvije varijable (Stewart i sur., 2021).

Osiguravanje pozitivnoga afekta u okružjima za učenje smatra se vrijednim. S robotima koji se koriste u poučavanju kodiranja, učenici mogu fizički dodirnuti sustave elektroničkih krugova i robota. Tako učenici smatraju predavanja zabavnijima i zanimljivijima (Eteokleous-Grigoriou i Psomas, 2013; Stewart i sur., 2021). Slično tome, korištenje robota u poučavanju kodiranja pokazalo se da povećava motivaciju učenika za lekciju i stvara dugotrajnije i smislenije učenje (Ersoy i sur., 2011). Istraživači tvrde da obrazovna istraživanja trebaju usmjeriti pozornost na načine kako potaknuti pozitivne afekte učenika. Također se preporučuje da se provedu daljnje eksperimentalne studije o razvoju pozitivnih afekta učenika (Pekrun i sur., 2002).

Metodologija

Za ovo se istraživanje rabio kvazieksperimentalni plan s predtestom i posttestom u kontrolnoj grupi. Plan istraživanja prikazan je u Tablici 1.

Tablica 1
Plan istraživanja

Grupa	Predtest	Poučavanje robotike (5 tjedana)	Posttest
Eksperimentalna grupa	Vještine kodiranja Vještine računalnoga razmišljanja	Metoda problemskoga *učenja* Pozitivan afekt	Vještine kodiranja Vještine računalnoga razmišljanja
Kontrolna grupa	Vještine kodiranja Vještine računalnoga razmišljanja	Tradicionalna metoda	Vještine kodiranja Vještine računalnog razmišljanja

Kako se vidi u Tablici 1, poučavanje robotike u eksperimentalnoj grupi provedeno je metodom PBL-a, dok je u kontrolnoj grupi primijenjena tradicionalna metoda. U obje grupe, eksperimentalne i kontrolne, mjerene su vještine kodiranja i vještine računalnoga razmišljanja (CT) prije i nakon poučavanja robotike. Osim toga, pozitivna afektivna stanja identificirana su tijekom eksperimentalnoga procesa u eksperimentalnoj grupi.

Sudionici

Istraživačka skupina sastoji se od 190 učenika petih razreda (11 – 12 godina). Međutim, 12 učenika isključeno je u fazi evaluacije istraživačkih podataka jer nisu pristupili jednom ili više testova provedenih tijekom istraživačkoga procesa. Istraživanje je provedeno sa 178 učenika koji pohađaju predmet Informacijske tehnologije i softver, od čega je 104 učenika bilo u eksperimentalnoj grupi, a 74 u kontrolnoj grupi.

Alati za prikupljanje podataka

Za prikupljanje podataka u istraživanju korišteni su test vještina kodiranja, ljestvica vještine računalnoga razmišljanja (CT) i ljestvica pozitivnoga afekta.

Test vještina kodiranja

Istraživač je razvio test vještina kodiranja. Test vještina kodiranja pripremljen je uzimajući u obzir aktivnosti usmjerene na poučavanje kodiranja među obrazovnim ciljevima 5. razreda iz predmeta Informacijske tehnologije i softver. Razvojne faze testa prikazane su na Slici 2.

Slika 2.

Prosječni indeks težine stavki pripremljenoga testa iznosio je 0,53, dok je prosječni indeks diskriminacije stavki bio 0,61. Cronbachov alfa koeficijent pouzdanosti testa iznosio je 0,86. Razvijeni test primijenjen je svim učenicima koji su sudjelovali u istraživanju kao predtest i posttest.

Skala CT vještina

Za ispitivanje utjecaja učenja robotskoga kodiranja, dizajniranoga prema PBL pristupu, na vještine računalnoga razmišljanja učenika korištena je ljestvica percepcije samoučinkovitosti za vještine računalnoga razmišljanja (CTS) koju su razvili Gülbahar i sur. (2019). Ljestvica od 36 stavki koristi 3-stupanjski Likertov format. Cronbachov alfa koeficijent pouzdanosti ljestvice iznosio je 0,943.

Ukupni bodovi koje učenici mogu dobiti na ljestvici kreću se od 36 do 108. Niska ukupna ocjena koju učenici dobiju na ljestvici ukazuje na visoku razinu CT vještina (Gülbahar i sur., 2019). Razlog za ovaj obrnuti odnos jest taj što su učenici s visokim CT vještinama bili usmjereni na označavanje nižih ocjena na ljestvici. CTS je primijenjen svim učenicima koji su sudjelovali u istraživanju, uključujući predtest i posttest. Cronbachov alfa koeficijent pouzdanosti, izračunat na temelju podataka istraživačke skupine, iznosi 0,91.

Skala pozitivnoga afekta

Korišten je odjeljak ljestvice pozitivnoga afekta iz ljestvice „Skala pozitivnog i negativnog afekta (PANAS)“ koju su razvili Watson i sur. (1988). Ova ljestvica korištena je kako bi se ispitali pozitivni afekti pri učenju robotskoga kodiranja dizajniranoga prema PBL pristupu na učenike. Deset stavki PANAS-a (primjeri stavki: zainteresiran, uzbuđen, entuzijastičan), koje se sastoje od 20 stavki, mjere pozitivan afekt. Preostalih 10 stavki mjeri negativne emocije. Najniži rezultat koji se može dobiti na ljestvici Likertova tipa s 5 stupnjeva je 1, a najviši 50. Visok rezultat na pozitivnim stavkama ljestvice ukazuje na pozitivan afekt; visoki rezultati na negativnim stavkama ukazuju na negativan afekt. Mogu se dobiti zasebni rezultati za svaki faktor s ljestvice ili se može koristiti ukupan rezultat. U istraživanju je korištena samo ljestvica pozitivnoga afekta. Razlog tomu je što ljestvica negativnih emocija sadrži stavke koje nisu prikladne za upotrebu u istraživanju (npr. uznemiren, uplašen, kriv, preplašen, neprijateljski raspoložen, nervozan, posramljen, razdražljiv, uplašen). Budući da je u istraživanju stvoreno strukturirano obrazovno okružje, nije se željelo uključiti negativne emocije.

Analiza Cronbachove alfe pokazala je da je koeficijent pouzdanosti ljestvice za pozitivan afekt 0,83 (Gençöz, 2000). Ljestvica pozitivnoga afekta primijenjena je na učenike eksperimentalne skupine kao predtest i posttest za svaki PBL scenarij. Cronbachov alfa koeficijent pouzdanosti, izračunat za pozitivan afekt u istraživanju, iznosi 0,86 za scenarij 1; 0,90 za scenarij 2; 0,88 za scenarij 3; 0,93 za scenarij 4 i 0,92 za scenarij 5.

Postupci

Aktivnosti provedene tijekom poučavanja robotike opisane su u dva dijela: priprema prije poučavanja robotike i poučavanje robotike.

Priprema prije poučavanja robotike

Priprema PBL scenarija. Posebna pažnja posvećena je tome da su PBL scenariji koje je razvio istraživač prilagođeni razini učenika kako bi im pomogli da steknu ishode iz nastavne teme „Programiranje“ u nastavnoj cjelini „Rješavanje problema i programiranje“. Odnos između pripremljenih PBL scenarija i ishoda prikazan je u Tablici 2.

Tablica 2
Odnos Između PBL Scenarija i Ishoda

Ishodi predmeta Kodiranje u primijenjenoj robotici	Scenarij 1	Scenarij 2	Scenarij 3	Scenarij 4	Scenarij 5
1. Može prepoznati sučelje i značajke alata za programiranje temeljenoag na blokovima.	x				
2. Može stvoriti ispravan algoritam za postizanje ciljeva u okružju za programiranje temeljenom na blokovima.	x	x	x	x	x
3. Može objasniti strukturu linearne logike.	x		x	x	
4. Može razviti algoritme koristeći strukturu linearne logike.	x		x	x	
5. Može objasniti strukturu odluka i funkcije.		x		x	x
6. Može razviti algoritme koji uključuju strukturu odluka.		x		x	x
7. Može objasniti strukturu petlje i funkcije.		x	x	x	x
8. Može stvoriti algoritme koji sadrže strukturu petlje.		x	x	x	x
9. Može otkloniti greške predviđanjem rezultata algoritama stvorenih za različite strukture.			x		

Tijekom pripreme PBL scenarija, u svakom su scenariju predstavljeni problemi iz stvarnoga života kako bi se pobudila znatiželja učenika i olakšala njihova motivacija.

Zatim su uključeni izrazi koji potiču i usmjeravaju učenike na rješavanje problemske situacije. Osim toga, u scenarije su dodani vizualni prikazi kako bi ih učinili zanimljivijima i motivirajućima. Pripremljene PBL scenarije pregledala su tri stručnjaka iz područja (nastavnici s doktoratom iz računalnoga obrazovanja i tehnologije poučavanja (CEIT)) kako bi se utvrdila njihova prikladnost za PBL pristup i ciljane ishode. U skladu s mišljenjima stručnjaka, izvršene su potrebne izmjene i scenariji su pripremljeni za poučavanje robotike.

Postupak prije poučavanja robotike prikazan je u Tablici 3.

Tablica 3
Postupak prije nastave robotike

Tjedni	Obavljene aktivnosti
1. → tjedan	Identifikacija ishoda
2. → tjedan	Priprema PBL scenarija
3. → tjedan	Primitak stručnih mišljenja o PBL scenarijima i izvođenje potrebnih revizija
4. → tjedan	Razvoj nacrta testa vještina kodiranja
5. → tjedan	Primitak stručnoga mišljenja o testu vještina kodiranja i izvođenje potrebnih revizija
6. → tjedan	Pokusno izvođenje testa vještina
7. → tjedan	Analiza testa vještina kodiranja

Poučavanje robotike. Teško je znati koje značajke tretmana mogu objasniti bilo kakve očite koristi. Iz toga razloga, proces poučavanja robotike bio je pažljivo planiran. Tretman je proveden na učenicima 5. razreda. Učenici prije toga nisu imali nikakvu pouku o robotskom kodiranju. Stoga se smatralo da učenici neće imati predrasude prema predmetu i učitelju. Isti učitelj uključen je i u eksperimentalnu i kontrolnu skupinu. Pokušalo se spriječiti moguće razlike među učiteljima. Osigurane su informacije kako bi se osiguralo da učitelj ne bude podložan utjecaju eksperimentalne ili kontrolne skupine. Obje skupine prethodno su imale nastavu fokusiranu na PBL u oba razreda. Tako se pokušalo spriječiti moguće situacije koje bi mogle proizaći iz novosti PBL okružja i dovesti do pogrešnih podataka istraživanja.

Tijekom tretmana, svim učenicima u eksperimentalnoj i kontrolnoj skupini poučavano je robotsko kodiranje, a korišteni su mBlock softver za kodiranje temeljen na blokovima i mBot robotski set. Istraživač je proveo obuku o robotskom kodiranju i proces prikupljanja podataka tijekom tretmana. Koraci procesa su sljedeći:

1. Poučavanje robotskoga kodiranja u eksperimentalnoj skupini provedeno je kroz problemske scenarije koje je razvio istraživač, dok su u kontrolnoj skupini korištene tradicionalne metode poučavanja. Nastava robotike trajala je 5 tjedana i 10 školskih sati. Proces tretmana prikazan je na Slici 3.

Slika 3

2. Nastava za obje eksperimentalne i kontrolne skupine proveden je u istoj informatičkoj učionici, a učionica je pripremljena u smislu softverskih i hardverskih resursa prije nastave.
3. Prije početka tretmana, učenicima u eksperimentalnoj skupini pružene su informacije o PBL pristupu, a također su im prikazani neki primjeri problematičnih scenarija.
4. Učenici u eksperimentalnoj skupini podijeljeni su u grupe od pet ili šest osoba. Skupine su mješovite u smislu spola, sposobnosti, uspjeha, socijalnih i osobnih karakteristika. U tu svrhu uzete su u obzir zapažanja istraživača koji je također bio učitelj informatike u istoj školi u kojoj je studija provedena.
5. Skala pozitivnoga afekta primijenjena je na učenike u eksperimentalnoj skupini prije i nakon svakog PBL scenarija tijekom tretmana.
6. Tretman je trajao sedam tjedana, uključujući predtestiranje i posttestiranje za sve učenike.

Eksperimentalna skupina. Eksperimentalna je skupina poučavana kroz PBL scenarije koje je pripremio učitelj/istraživač . Istraživač je učitelj relevantnoga nastavnog predmeta. Tijekom pet tjedana nastave robotike, koliko je trajala nastava, učitelj/istraživač je svakom učeniku na početku predavanja podijelio scenarije, po jedan scenarij tjedno, nakon što je najavio ciljeve. Na taj su način učenici, koji su se suočili s nestrukturiranim problemskim situacijama, primijetili problem u scenarijima, koristili internetske resurse kako bi izradili svoja rješenja, a zatim ih zapisali u odgovarajući dio scenarija. Kako su učenici nalazili svoja rješenja, mogli su u bilo kojem trenutku komunicirati sa svojim učiteljima ili članovima tima i međusobno dijeliti informacije koje su upravo otkrili. Zatim su svi učenici u skupinama raspravljali o svojim rješenjima i dogovarali zajedničko rješenje koje su zatim zapisali u odgovarajući dio scenarija u ime svoje skupine. Svaka je skupina predstavila svoja rješenja ostalim učenicima u razredu. Na kraju, učitelj/istraživač je procijenio rezultate i došlo se do konačnoga rješenja problema.

Učitelj/istraživač je tijekom vođenja procesa i učenika davao povratne informacije o učenju u eksperimentalnoj grupi. U tom je smjeru istraživač/učitelj postavljao pitanja učenicima u skladu s PBL scenarijima (Dodatak 1 – Scenarij korišten u nastavi robotike) i poticao učenike da istražuju, postavljaju pitanja i donose odgovarajuće odluke. Međutim, učitelj/istraživač nije izravno odgovarao na postavljena pitanja, već je poticao učenike da sami pronađu pravi odgovor. Istraživač/učitelj pomogao je u stvaranju dinamike u grupi, motivirajući učenike i dajući povratne informacije o njihovom učenju, a ponekad je sudjelovao u aktivnostima učenika. Eksperimentalna skupina prikazana je na Slici 4.

Slika 4

Kontrolna skupina. U kontrolnoj se skupini nastava izvodila tradicionalnim metodama poučavanja. Tradicionalno učenje je oblik prakse u kojem se koriste metode kao što su predavanje, pitanja i odgovori te rasprava pod vodstvom učitelja. Tradicionalna metoda poučavanja usmjerena je na učitelja, pri čemu učitelj odlučuje o tijeku lekcije, kako će učenici biti vođeni i kako će se vršiti ocjenjivanje. Učenik je pasivni primatelj i imitator, pa je način učenja dobra imitacija učitelja. Na taj je način u kontrolnoj grupi usvojen tradicionalni pristup učenju.

Tijekom pet tjedana nastave robotike, učitelj/istraživač je na početku sata objasnio relevantnu temu učenicima samo kroz izlaganje i metode pitanja i odgovora, nakon što je najavio ciljeve. Zatim su učenici mogli sudjelovati u nastavi pokazujući kako se to radi te im je omogućeno da sami to izvedu. Na kraju je sat završio sažimanjem teme nakon rasprave u razredu.

U kontrolnoj je skupini učitelj/istraživač imao ulogu u predstavljanju sadržaja nastave, vođenju rasprava, postavljanju pitanja i izravnom odgovaranju na pitanja učenika. Međutim, istraživač/učitelj je također davao povratne informacije o učenju motivirajući učenike. Kontrolna skupina prikazana je na Slici 5.

Slika 5

Situacije ispitivane u istraživanju mjerene su tjedno. Jedan od razloga za to je način korištenja skala. Drugi i glavni razlog jest taj što se emocionalna stanja i mišljenja o događajima mogu mijenjati tijekom tjedna. Proces tretmana prikazan je u Tablici 4.

Tablica 4
Proces tretmana

Tjedni	Obavljene aktivnosti
1. tjedan	Provođenje predtestova (test vještina kodiranja i CTS)
2. tjedan	Predtestiranje skale pozitivnoga afekta u eksperimentalnoj skupini
	Eksperimentalna skupina - robotičko kodiranje s PBL Scenarijem 1
	Posttestiranje skale pozitivnoga afekta u eksperimentalnoj skupini
	Kontrolna skupina - robotičko kodiranje 1 s tradicionalnom metodom
3. tjedan	Predtestiranje skale pozitivnoga afekta u eksperimentalnoj skupini
	Eksperimentalna skupina - robotičko kodiranje s PBL Scenarijem 2
	Posttestiranje skale pozitivnoga afekta u eksperimentalnoj skupini
	Kontrolna skupina - robotičko kodiranje 2 s tradicionalnom metodom
4. tjedan	Predtestiranje skale pozitivnoga afekta u eksperimentalnoj skupini
	Eksperimentalna skupina - robotičko kodiranje s PBL Scenarijem 3
	Posttestiranje skale pozitivnoga afekta u eksperimentalnoj skupini
	Kontrolna skupina - robotičko kodiranje 3 s tradicionalnom metodom
5. tjedan	Predtestiranje skale pozitivnoga afekta u eksperimentalnoj skupini
	Eksperimentalna skupina - robotičko kodiranje s PBL Scenarijem 4
	Posttestiranje skale pozitivnoga afekta u eksperimentalnoj skupini
	Kontrolna skupina - robotičko kodiranje 4 s tradicionalnom metodom

Tjedni	Obavljene aktivnosti
6. tjedan	Predtestiranje skale pozitivnoga afekta u eksperimentalnoj skupini
	Eksperimentalna skupina - robotičko kodiranje s PBL Scenarijem 5
	Posttestiranje skale pozitivnoga afekta u eksperimentalnoj skupini
	Kontrolna skupina - robotičko kodiranje 5 s tradicionalnom metodom
7. tjedan	Provođenje posttestiranja (Test vještina kodiranja i CTS)

Analiza podataka

Kolmogorov-Smirnov test korišten je za testiranje normalne distribucije dobivenih rezultata. Kao što je utvrđeno testovima normalnosti, korišten je T-test za zavisne uzorke iz parametrijskih testova za podatke s normalnom distribucijom, Mann-Whitney U-test iz neparametrijskih testova za međugrupne podatke koji nisu normalno distribuirani i Wilcoxonov test iz neparametrijskih testova za unutargrupne podatke koji nisu normalno distribuirani. Osim toga, izvedena je ANCOVA analiza kako bi se utvrdio stvarni učinak eksperimentalnoga tretmana statističkom provjerom drugih varijabli povezanih s zavisnom varijablom, osim nezavisne varijable čiji je učinak testiran u istraživanju (Büyüköztürk, 2004). Sve statističke analize temeljile su se na razini značajnosti od 0,05. Kada postoji značajna razlika u izračunatim rezultatima, vrijednost eta-kvadrata (η2) veličine učinka izračunata je i interpretirana na sljedeći način: mala ako je 0,01-0,06, srednja ako je 0,06-0,14, visoka ako je 0,14 i više (Cohen, 1988).

Rezultati

Rezultati u vezi s utjecajem PBL pristupa na vještine kodiranja

Kako bi se ispitala učinkovitost robotskoga kodiranja dizajniranog aprema PBL pristupu na vještine kodiranja učenika srednjih škola (starijih razreda osnovnih škola, op. prev.), uspoređene su unutargrupne i međugrupne vještine kodiranja eksperimentalnih i kontrolnih skupina na temelju njihovih rezultata predtesta i posttesta. Unutargrupne vještine kodiranja eksperimentalnih i kontrolnih skupina uspoređene su korištenjem T-testa za zavisne uzorke (Tablica 5).

Tablica 5

Kada se promotri Tablica 5, vidi se da postoje značajne razlike između rezultata predtesta i posttesta u vještinama kodiranja učenika eksperimentalne i kontrolne skupine ($p = 0{,}000 < 0{,}05$ za eksperimentalnu i kontrolnu skupinu). Razlike su u korist posttesta. Kada se ispitaju prosječne ocjene obaju testova, vidi se porast u rezultatima vještina kodiranja i eksperimentalne i kontrolne skupine.

U usporedbi rezultata vještina kodiranja između eksperimentalne i kontrolne skupine, uspoređeni su rezultati predtesta vještina kodiranja obje skupine. Budući da rezultati predtesta vještina kodiranja obje skupine nisu imali normalnu distribuciju, skupine su uspoređene Mann-Whitney U testom.

Kada se promotri Tablica 6, vidi se da nema značajne razlike između rezultata predtesta vještina kodiranja učenika eksperimentalne i kontrolne skupine ($p = 0{,}666 > 0{,}05$). Prema tome, može se tvrditi da je prethodno znanje o vještinama kodiranja eksperimentalne i kontrolne skupine slično. Stoga su uspoređeni rezultati posttesta vještina kodiranja obje skupine. Budući da vještine kodiranja obje skupine nisu imale normalnu distribuciju u podatcima posttesta, skupine su uspoređene Mann-Whitney U testom.

Tablica 6

Kada se promotri Tablica 6, vidi se da postoji značajna razlika između rezultata posttesta vještina kodiranja učenika eksperimentalne i kontrolne skupine ($p = 0{,}025 < 0{,}05$). Ova razlika je u korist eksperimentalne skupine. Drugim riječima, rezultati posttesta vještina kodiranja eksperimentalne skupine ($\overline{X} = 13{,}90$) značajno su viši od rezultata posttesta vještina kodiranja kontrolne skupine ($\overline{X} = 12{,}65$).

Rezultati o učinku PBL pristupa na CT vještine

Kako bi se ispitao učinak poučavanja robotskoga kodiranja dizajniranoga prema PBL pristupu na vještine računalnoga razmišljanja učenika, uspoređeni su rezultati predtesta i posttesta unutar skupine za vještine računalnoga razmišljanja (CTS) i međugrupni rezultati CTS-a eksperimentalne i kontrolne skupine. T-test za zavisne uzorke korišten je za usporedbu predtesta i posttesta vještina računalnoga razmišljanja eksperimentalne skupine. Budući da podatci nisu imali normalnu distribuciju, Wilcoxonov test korišten je za usporedbu predtesta i posttesta vještina računalnoga razmišljanja kontrolne skupine (Tablica 7).

Tablica 7

Kada se promotri Tablica 7, vidi se da postoje značajne razlike između rezultata predtesta i posttesta CTS-a učenika eksperimentalne i kontrolne skupine ($p = 0{,}000 < 0{,}05$ za eksperimentalnu i kontrolnu skupinu). Ove razlike su u korist posttesta. Kada se ispitaju prosječne ocjene obje skupine, vidi se smanjenje rezultata CTS-a. Smanjenje ukupnoga rezultata koji su učenici dobili na skali ukazuje na to da je razina vještina računalnoga razmišljanja porasla (Gülbahar i sur., 2019).

U usporedbi rezultata CTS-a eksperimentalne i kontrolne skupine, najprije su uspoređeni rezultati predtesta CTS-a obje skupine. Budući da rezultati predtesta kontrolne skupine nisu imali normalnu distribuciju, Mann-Whitney U test korišten je za usporedbu rezultata predtesta obiju skupina (Tablica 8).

Tablica 8

Kada se promotri Tablica 8, vidi se da postoji značajna razlika između rezultata predtesta CTS-a učenika eksperimentalne i kontrolne skupine ($p = 0{,}003 < 0{,}05$). Utvrđeno je da je ova razlika u korist učenika u kontrolnoj skupini.

ANCOVA analiza korištena je za usporedbu rezultata CTS-a eksperimentalne i kontrolne skupine, budući da je postojala značajna razlika između rezultata predtesta

CTS-a eksperimentalne i kontrolne skupine. U tom kontekstu, rezultati predtesta CTS-a eksperimentalne i kontrolne skupine uzeti su kao kontrolne varijable, a uspoređeni su prilagođeni rezultati posttesta skupina. Tablica 9 prikazuje deskriptivne statistike za rezultate CTS predtesta, posttesta i prilagođenoga posttesta obiju skupina.

Tablica 9

U Tablici 10 prikazan je rezultat ANCOVA analize u kojoj su uspoređeni prilagođeni rezultati CTS posttesta eksperimentalne i kontrolne skupine.

Tablica 10

Kada se promotri Tablica 10, vidi se da postoji statistički značajna razlika između rezultata CTS-a učenika eksperimentalne i kontrolne skupine kada su rezultati predtesta kontrolirani ($p = 0{,}009 < 0{,}05$). Postoji razlika između CTS rezultata skupina u korist eksperimentalne skupine, neovisno o rezultatima predtesta.

Rezultati o učinku PBL pristupa na pozitivna afektivna stanja

Za svaku PBL situaciju korišten je Wilcoxonov test za usporedbu rezultata predtesta i posttesta pozitivnoga afekta, budući da podatci nisu imali karakteristike normalne distribucije (Tablica 11).

Tablica 11

Kada se promotri Tablica 11, vidi se da za svaku PBL situaciju postoje značajne razlike između rezultata predtesta i posttesta pozitivnoga afekta učenika eksperimentalne skupine ($p = 0{,}000 < 0{,}05$). Ove razlike su u korist posttestnih podataka. Drugim riječima, rezultati pozitivnoga afekta eksperimentalne grupe značajno su porasli u svakoj od PBL situacija.

Rasprava

Promatranjem rezultata vještina kodiranja, primijećeno je da su se vještine kodiranja i eksperimentalne i kontrolne skupine značajno povećale na kraju tretmana. Međutim, vještine kodiranja učenika eksperimentalne skupine bile su značajno više od vještina kodiranja učenika kontrolne skupine. Drugim riječima, utvrđeno je da poučavanje robotskoga kodiranja dizajniranoga prema PBL pristupu ima pozitivan učinak na vještine kodiranja učenika. Učiteljima su potrebne dobro isplanirane strategije kako bi ih vodile u integraciji računalnoga razmišljanja (CT) u njihove obrazovne procese (Israel-Fishelson i sur., 2021; Lockwood i Mooney, 2017). Rezultati istraživanja pokazali su da se vještine povezane s CT-om poboljšavaju ako se ova potreba može zadovoljiti. Istraživanje je također vrijedno jer nudi planiranje koje će voditi učitelje u postizanju vještina CT-a u nastavi kodiranja. Međutim, u relevantnoj literaturi postoje vrlo mali primjeri planova učitelja za poučavanje robotskoga kodiranja dizajniranoga prema PBL pristupu. Lykke i sur. (2014) proveli su eksperimentalno istraživanje i primijenili PBL dizajn te su otkrili da učenici primjećuju da roboti učinkovito pomažu u razvoju vještina kodiranja i motivacije učenika. Ovo istraživanje podržava zaključak da poučavanje robotskoga kodiranja, dizajniranoga prema PBL pristupu u ovom istraživanju, povećava vještine kodiranja učenika.

Kad se promotre nalazi povezani s vještinama CT-a, primijećeno je da su razine vještina CT-a i eksperimentalne i kontrolne skupine značajno povećane na kraju tretmana. Nalazi istraživanja koji tvrde da korištenje robota u poučavanju kodiranja povećava vještine CT-a učenika (Baek i sur., 2019; Bers i sur., 2019; Chalmers, 2018; Constantinou i Ioannou, 2018; Luo i sur., 2020; Roussou i Rangoussi, 2020; Stewart i sur., 2021; Sullivan i sur., 2017; Wu i Su, 2021) podržavaju jedni druge. Osim toga, vještine CT-a učenika u eksperimentalnoj skupini bile su značajno više od vještina učenika u kontrolnoj skupini. Drugim riječima, utvrđeno je da poučavanje robotskoga kodiranja dizajniranoga prema PBL pristupu ima pozitivan učinak na vještine CT-a učenika. Odnos CT-a s ishodima dobro planiranih praksi kodiranja (Garcia-Penalvo i Mendes, 2018) također je potvrđen ovom studijom. Nalazi istraživanja koji tvrde da organiziranje aktivnosti rješavanja problema u kurikulu robotike prema njihovoj prirodi poboljšava vještine CT-a učenika (Angeli i Valanides, 2019; Caballero-Gonzalez i sur., 2019; Chen i sur., 2017; Kale i Yuan, 2021) također bi se mogli smatrati podrškom nalazima ovoga istraživanja. Također je poznato da CT pomaže u razvoju vještina rješavanja problema (Grover i Pea, 2013; Wing, 2008). Ovom studijom utvrđeno je da razvoj vještina rješavanja problema također poboljšava CT. Ono što iznenađuje istraživača jest da bi odnos između CT-a i vještina rješavanja problema mogao biti dvostrano orijentiran.

Kad se razmotre nalazi vezani za pozitivan afekt, primijećeno je da svaki od problema scenarija danih eksperimentalnoj skupini prema PBL pristupu tijekom tretmana značajno povećava njihov pozitivan afekt. Također bi se moglo tvrditi da pobuđivanje pozitivnoga afekta učenika povećava njihov uspjeh (Konradt i sur., 2003; Lyubomirsky i sur., 2005; Pekrun i sur., 2002). Haapasalo i Samuels (2011) tvrde da užitak koji se osjeća kroz robotiku u matematičkom obrazovanju može povećati motivaciju učenika za učenje. Postizanje motivacije povezano je s pozitivnim afektom (Pekrun i sur., 2002). Stewart i sur. (2021) također tvrde da motivirani učenici mogu pokazati bolje vještine rješavanja problema. Slično tome, Ersoy i sur. (2011) navode da korištenje robota u poučavanju kodiranja povećava motivaciju u nastavi, stvarajući dugotrajnije i značajnije učenje. Činjenica da su vještine kodiranja i vještine CT-a učenika eksperimentalne skupine, koji su poučavani robotskom kodiranju PBL pristupom, značajno više od učenika kontrolne skupine koji su poučavani robotskom kodiranju tradicionalnim pristupom, podržava istraživanje u relevantnoj literaturi.

Unutar svih rezultata dobivenih ovim istraživanjem, poučavanje robotskoga kodiranja dizajniranoga prema PBL pristupu doprinosi literaturi u kontekstu mreže odnosa vještina kodiranja, CT-a, vještina rješavanja problema i pozitivnoga afekta.

Zaključak

Vještina CT-a je vrlo kompleksna za evaluaciju zbog svoje složene prirode koja uključuje mnoge procese kao što su kritičko, kreativno i algoritamsko razmišljanje, rješavanje problema, komunikacijske vještine i suradnički rad (Gülbahar i sur., 2019; Yeni, 2017). Velika slika istraživanja sažeta je u Slici 6.

Slika 6

Na kraju tretmana, vještine kodiranja u eksperimentalnoj i kontrolnoj skupini su se značajno povećale. Drugim riječima, utvrđeno je da edukativni robotički kompleti korišteni u obje skupine pozitivno utječu na vještine kodiranja. Vještine kodiranja učenika eksperimentalne skupine bile su značajno više od vještina kodiranja učenika kontrolne skupine. Drugim riječima, otkriveno je da poučavanje robotičkoga kodiranja dizajniranoga prema PBL pristupu ima pozitivan učinak na učeničke vještine kodiranja.

Na kraju tretmana razine CT vještina u eksperimentalnoj i kontrolnoj skupini značajno su porasle. Drugim riječima, utvrđeno je da korištenje edukativnih robotičkih kompleta u poučavanju kodiranja ima pozitivan učinak na CT vještine. CT vještine učenika u eksperimentalnoj skupini bile su značajno više od CT vještina kontrolne skupine. Drugim riječima, istraživanje je pokazalo da se CT vještine mogu poboljšati kroz kurikul organiziran prema PBL pristupu.

Tijekom tretmana, svaki od problemskih scenarija danih eksperimentalnoj skupini prema PBL pristupu značajno je povećao pozitivan afekt studenata. Moglo bi se tvrditi da aktivacija pozitivnoga afekta učenika može biti učinkovita u povećanju njihovog uspjeha. U istraživanju, činjenica da su vještine kodiranja i CT vještine učenika eksperimentalne skupine koji su poučavani robotičkom kodiranju putem PBL pristupa bile značajno više od onih učenika kontrolne grupe koji su poučavani robotičkom kodiranju tradicionalnim pristupom podržava ovu spoznaju.

U ovome je istraživanju kurikul organiziran s PBL pristupom. Tako su se pokušale aktivirati CT vještine. Mogla bi se stvoriti okružja za kodiranje u kojima su nastavni programi organizirani unutar različitih okvira. Organiziranjem kurikula s različitim pristupima mogli bi se ispitati njihovi učinci na CT vještine. Tako bi se mogli istražiti načini za postizanje tih vještina. U budućnosti, slična istraživanja mogla bi se provesti s učenicima različitih dobnih skupina, a mogle bi se ispitati i različite varijable kao što su rješavanje problema, kreativno razmišljanje, sposobnost kritičkoga razmišljanja, motivacija i stavovi. Mogu se koristiti različiti robotički kompleti i različita okružja za kodiranje te usporediti dobivene rezultate. U ovome je istraživanju učinak poučavanja robotičkoga kodiranja dizajniranoga prema PBL pristupu na CT vještine učenika procijenjen na temelju ukupnoga rezultata podfaktora CTS-a. U budućim istraživanjima, pet podfaktora moglo bi se ispitati pojedinačno. Učenici kontrolne skupine učili su robotičko kodiranje tradicionalnom metodom, dok se zbog prevelikoga broja učenika u razredu i troškovnih faktora nije moglo dodijeliti pojedinačni robotički komplet svakom učeniku. Stoga su učenici morali izvoditi svoje kodiranje sa sedam robotičkih kompleta. U budućim istraživanjima, ovaj bi razmak mogao biti ispravljen i dobiveni bi se rezultati mogli usporediti. S druge strane, mogu se dizajnirati istraživanja za ispitivanje učinkovitoga broja članova skupine koji koriste robotičke komplete. Osim toga, vještine kodiranja učenika u studiji mjerene su razvojem standardnoga testa postignuća zbog nedovoljnoga broja mBot robotičkih kompleta koji su korišteni. Praktični testovi mogli bi mjeriti učeničke vještine kodiranja.

Ograničenja

Istraživački proces detaljno je planiran. Priprema nastavnih priprava i materijala trajala je otprilike 6 mjeseci. U ovom procesu nastojalo se vizualizirati predeksperimentalni proces i trenutak eksperimentalnoga procesa, a moguća ograničenja su izbjegnuta. Međutim, istraživanje još uvijek ima određena ograničenja. Istraživači su međusobno raspravljali o sljedećim dvama ograničenjima:

1. Je li PBL napravio razliku ili je razlika nastala zbog grupnoga rada usmjerenoga na vršnjake?
2. Je li PBL napravio razliku ili ju je uzrokovala veća autonomija učenika eksperimentalne skupine? Ova pitanja trebaju se razmotriti u drugim istraživanjima.

Još jedno ograničenje jest to što je istraživanje ispitivalo percepcije samoučinkovitosti učenika u vezi s njihovim CT vještinama, a ne razinu njihovih CT vještina.

Osim toga, još jedno ograničenje studije jest to što je samo eksperimentalna grupa mjerena za pozitivan afekt. Istraživanje nije ispitivalo koja od eksperimentalne i kontrolne skupine ima viši pozitivan afekt; istraživalo se hoće li problemski scenariji aktivirati pozitivan afekt učenika. U drugim studijama mogu se usporediti pozitivna stanja afekta eksperimentalne i kontrolne skupine.

Dodatak 1. Primjer scenarija

mBot rješenje za isključenja struje

Orkun provodi svoje ljetne praznike na selu sa svojim djedom. Dok je ondje, pomaže djedu u nekim poslovima. Navečer čita knjige. Međutim, u selu često dolazi do isključenja struje. Djed i Orkun ostaju u tami. Orkun misli da može riješiti ovaj problem s robotskim kodiranjem koje su naučili na predmetu Informatika. Razvija projekt i govori djedu o tome.

Orkun: Djede, odlučio sam dizajnirati robota koji će nas spasiti od tame kada dođe do isključenja struje. Za to ću koristiti mBot komplet. mBot će se automatski upaliti kada dođe do isključenja struje i kada okolina postane tamna. Isključit će se kada se struja vrati i okolina postane svijetla.

Djed: To je sjajna ideja, Orkune! Ovaj robot će nam puno pomoći kada nestane struje. Spasit će nas od tame kada nestane struje. Ali kako ćeš to napraviti?

Orkun: ...