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# HOW ROBOTIC CODING EDUCATION AFFECTS SECONDARY SCHOOL STUDENTS' PROBLEM-SOLVING SKILLS AND THEIR VIEWS ON CODING ACTIVITIES

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**ABSTRACT**

The primary purpose of this study is to contribute to developing skills such as critical thinking and creative thinking skills, especially problem-solving skills expected from 21st-century individuals, by providing coding education to students with the help of new technologies called robotics and programming with robotics in extracurricular hours. For this purpose, a five-week, one-group experimental study was designed to investigate the effects of robotic coding education on the problem-solving skills of middle school students and to understand students' views on robotic coding activities. The study participants comprised 26 volunteer students from a middle school in Kocaeli. The research method was based on a mixed design research design. Robotics Pre-Survey, Robotics Satisfaction Test, Children's Problem-Solving Inventory, and Activity Perception Scale were used, and observations and focus group interviews were conducted. According to the analysis of the collected data, the five-week robotic coding training significantly and positively contributed to students' problem-solving skills. Another study result was that the participating students were satisfied with the activities, their prior thoughts about robotics were positive, and they liked and enjoyed the activities.

**Keywords:** Robotics, Robotics Coding, Problem Solving, 21st Century Skill.

**INTRODUCTION**

In today's world, science and technology are changing rapidly; this change changes the needs of the individual and society and directly affects the roles assigned to individuals in the community. Individuals are expected to produce knowledge, solve problems, have communication and cooperation skills, think critically and creatively, and have 21st-century skills. In order to raise individuals with these qualities, innovations and developments in learning-teaching theories and approaches are inevitable (Ministry of National Education [MoNE], 2018). Changes in learning approaches require organizing learning environments and learning activities with the developing technology. The use of educational technologies in the creation of these environments emerges as a necessity rather than an alternative (Şişman & Küçük, 2017).

The Ministry of National Education has made it compulsory to teach the Information Technologies and Software course for two hours a week in grades K5 and K6. According to the Information Technologies and Software Course Curriculum (2018), it is aimed at students to gain primary computer usage and programming skills. The pieces of training to be given in the program are grouped under five basic units. Problem Solving and Programming unit is included in both 5th and 6th grades. Within the scope of the course, it is aimed that students gain problem-solving and computational thinking skills, learn and apply at least one of the programming languages to solve problems, and work collaboratively. In addition to being able to write computer programs, coding skills also provide skills such as problem-solving, looking at issues from different perspectives, and creative and critical thinking (Yükseltürk & Altıok, 2015).

Sayın and Seferoğlu (2016) addressed coding education within the 21st-century skills that individuals should have in order for countries to keep up with the development of the world and to raise the manpower that can meet the economic needs of the age. Looking at the research conducted around the world, it is seen that the importance of coding education is increasing, especially at an early age (Demirer & Sak, 2018). The type of coding education given, the programming language, and the choice of platform used are of great importance in providing coding education to individuals. Especially for individuals and children new to programming, the complex syntax of traditional programming languages can make learning difficult (Çatlak et al., 2015). To solve this problem and to motivate students, especially young children, tools such as "Alice", "Scratch", and "Code.org", which are more fun, easy to learn, and have visual features, have been developed. Such programs are tools for block-based programming that do not require writing lines of code. Robot programming is another method included in coding education as an alternative or support to block-based programs (Çankaya et al., 2017). With robotic sets, students can gain coding skills from the preschool period (Tekinarslan & Çetin, 2018).

In visual programming, students can create lines of code with drag-and-drop methods and try to understand the coding logic. However, many processes and concepts may remain abstract for students. Robotic coding can be seen as a new approach allowing students to concretize the knowledge they have learned (Ersoy et al., 2011).

Students can test their coding on robots and begin to explore computer programming concepts while trying to program robots (Earle, 2011).

The concept of robotics, which emerges as a new technology in education, creates an alternative for educators in teaching coding. Thanks to robots, students can meet coding and start writing code in an easier, more permanent, and effective way. Robotics education is fed by computer science and fields such as science, mathematics, and engineering. Robotics is used in STEM (Science, Technology, Engineering, and Mathematics) education, which is included in the education system of many countries and attracts great interest. The most common use of robots in education is to support STEM education. Most of the studies conducted in this field have resulted in the positive effect of robots in STEM education (Üçgül, 2013).

STEM education has started to be implemented in educational institutions in leading countries such as the United States, the European Union, Germany, China, Finland, and Korea. In these countries, efforts have been initiated to establish STEM centers, including project-inquiry-based learning, creativity, design and innovation activities, STEM activities, maker, programming, and robotics workshops. MoNE prepares no strategic plan for STEM education in Turkey. However, the 2015-2019 Strategic Plan gives targets for strengthening STEM. In line with these goals, although it is said that the objectives of the Technology and Design course and STEM objectives overlap in some points, it is seen that this situation is insufficient. STEM education should be essential to reach developed countries' education levels. In addition, in terms of supporting STEM education, it is predicted that providing individuals with a coding-based approach in the Computer Technologies curriculum is essential. (STEM Education Report, 2016). Coding education is an important and effective tool that can be used during STEM applications (Keçeci et al., 2017). Educational robots have been widely used in developed countries, especially in STEM education (Yolcu & Demirer, 2017). Educational robotics plays an essential role in students' learning STEM concepts, coding, computational thinking, and engineering skills in the learning process from kindergarten to university. Educational robotics is a technological learning tool that supports the future success of learners and should be included more and more in the school curriculum (Eguchi, 2014). It is indispensable to closely follow technological developments in robotics for a generation that can question, research, produce, think critically, and solve problems that our country needs.

With the effect of developing technologies and the ease of accessibility of robotics, educational robots have started to be used more and more in education, and robotic coding has started to make a name for itself in almost all levels of education. In this context, it is thought that the necessity of robotic coding education is no longer a matter of discussion, but the skills that this education will provide students should be emphasized. The extent to which 21st-century individuals can acquire the skills expected through robotic coding education is an important issue that needs to be investigated. When we look at the research conducted in Turkey, it can be said that the existing studies are mostly related to the field of mathematics and engineering, and there is a limited number of studies in the field of education. In our country, it is seen that robotic coding activities are carried out in environments such as courses given in schools, extracurricular club activities, and private workshops, but in the literature reviews, there are not enough research findings on robotic coding activities at primary and secondary education level (Kasalak, 2017).

**Problem-Solving Skills**

Problem, in a word, is defined as an obstacle that confronts the existing forces that an individual gathers in order to achieve the desired goal. On the other hand, John Dewey refers to things that challenge the human mind, confuse the mind, and obscure beliefs as problems (Bingham, 1983). In order to reach a goal, it is necessary to find the most appropriate method of overcoming obstacles (Morgan 1982, as cited in Serin, Serin, & Saygılı, 2010). Problem-solving is a process of thinking and overcoming the problem until the individual finds a solution to the difficulties encountered to reach a goal (Ülküer, 1988). Since problems are encountered in all areas of life, problem-solving skills should be taught to individuals early. In the last thirty years, many problem-solving strategies have been proposed to solve problems (Ünsal, 2006). Although different names call them, many strategies consist of similar steps. Polya (2004) discussed problem-solving techniques in his book "How To Solve It" in 1945. In this book, which has sold more than a million copies and been translated into 17 languages, four basic principles are described to guide students in solving their problems. These are understanding the problem, preparing a plan, implementing the plan, looking back, and reviewing the solution.

This study aims to provide coding education to students with the help of new technologies called robotics to contribute to developing the skills expected from 21st-century individuals, such as critical thinking and creative thinking skills, especially problem-solving skills, by programming with robotics in extracurricular hours. Therefore, the study attempts to answer the following research questions:

1. Does robotic coding education at the secondary school level affect students' problem-solving skills?
    a. Does robotic coding education given at the secondary school level affect students' confidence in problem-solving skills?
    b. Does robotic coding education given at the secondary school level affect students' self-control?
    c. Does robotic coding education given at the secondary school level affect students' avoidance behaviors?
2. What problems and challenges do students face in robotic coding education?

**METHOD**

This section should include subheadings such as the research model, population-sample, study group, data collection tools, validity-reliability, and data analysis. The pattern of the research should be explained in detail in this section. Instead of giving a theoretical definition of the method, the process should be explained in detail. Ethics committee approval should be detailed in the method section.

***Mixed-method Research***

In this study, mixed-method research was used to investigate the effects of robotic coding education on middle school students' problem-solving skills and students' views on robotic coding activities. A convergent mixed method design was used in the study, which is a type of design in which quantitative and qualitative data are collected in parallel, analyzed separately, and then combined (Büyüköztürk, 2016). In the quantitative part of the study, a one-group weak experimental method was applied to examine the effect of robotic coding activities on problem-solving skills. A weak experimental method in educational research refers to a study design or approach needing more rigor or significant limitations in establishing causal relationships between variables. This weakness can manifest in various ways, such as inadequate sample sizes, poorly controlled variables, flawed randomization processes, or insufficiently reliable measurement tools. This research encountered several compelling reasons to employ a weaker experimental method. First and foremost, resource constraints, including limited funding, time constraints, and challenges in participant recruitment, necessitated compromises in our study design. This inevitably resulted in a less robust experimental approach.

Moreover, the real-world complexity inherent in educational settings presented a formidable challenge. The dynamic nature of these environments made it impractical to implement tightly controlled experiments. In light of this, we deliberately sacrificed some degree of experimental control in favor of ecological validity. Additionally, we recognized the significance of pilot studies or exploratory research in the early stages of our investigation. These preliminary investigations were instrumental in uncovering potential trends or relationships. They played a crucial role in informing the development of more robust experimental designs for subsequent studies. By conducting these preliminary studies, we were able to refine our methodology and strengthen the overall validity of our research.

In the qualitative part of the study, the researcher kept observation reports as a participant observer and conducted focus group interviews with the students at the end of the five-week activities.

***Study Group of the Research***

The study group of the research consists of 26 students studying in the 5th, 6th, and 7th grades of a secondary school affiliated with the Directorate of National Education in Kocaeli province. The participants of the study were determined by convenience sampling technique.

**Tablo 1** Descriptive Data of the Robotic Coding Education Research Group

| Variable | Subgroup | N | % |
|---|---|---|---|
| Gender | Female | 8 | 30.8 |
| | Male | 18 | 69.2 |
| Grade Level | Grade 5 | 9 | 34.6 |
| | Grade 6 | 6 | 23.1 |
| | Grade 7 | 11 | 42.3 |

The participants were selected among the students who voluntarily participated in the study among the students who enrolled in the robotic coding workshops opened at the school. Descriptive statistics obtained from the demographic data of the students are shown in Table 1.

***The Role of the Researcher and the Environment in which the Study is Conducted***

It was decided to conduct the study in a school where a robotic coding workshop was planned to be opened, and the researcher created a teaching design suitable for the study. In this study, the researcher worked as a teacher, prepared the training content, and taught the lesson to the students. In addition, the researcher was involved as a "participant observer" to evaluate the students' experiences and the deficiencies in the educational process.

Robotic coding training was carried out in the STEM Laboratory of the school where the implementation was carried out. In the laboratory, which has an extensive working area, there is one smart board, one white whiteboard mounted on the wall, three desks for 12 students each, and 30 student chairs. Students were divided into two groups, and each group was provided with a laptop computer, a mouse, and a charger. In the first two weeks of the study, each student group received one Edison educational robot, and in the last three weeks, each group received one Makeblock mBot robot. EdWare software was used to program Edisons, and mBlock v3.4.12 software was used to program mBots. Although the software and robots differ, the robotic coding algorithm is the same.

***Implementation Process of the Research***

First, a pilot study was conducted with 15 students in another middle school. In this study, the researcher applied the problem-solving inventory to 15 students through pre-test and post-test and collected data through observation and focus group interviews. A 4-week training program was implemented with educational robots. As a result of the pilot study, corrections that could be made on issues such as redesigning the process, the duration and format of the questionnaires, the activities and the time given to the activities, in-class arrangements, technical problems that may be encountered, deficiencies in observation and interview forms were noted. Additions and deletions were made to the activities carried out in the pilot study. At the end of the pilot study, a 5-week study plan was prepared.

After the pilot study was reorganized, the research was conducted in the selected middle school. Before starting the robotic coding training with the students, the lesson was taught with traditional methods for three weeks, the students and the learning environment were recognized, and the researcher and the students were integrated. The "Problem-Solving Inventory for Children" and "Robotics Preliminary Questionnaire" were administered before starting the activities so as not to affect the course time in the week when the training started for the research. Students were divided into two groups from the previous weeks, and each group was given a laptop and Edison educational robot. The lesson was explained with the help of a smart board, and the robots were introduced. In addition, worksheets were prepared and distributed to the students for each subject. Lecture, question-answer, brainstorming, and problem-solving techniques were used during the course.

The first week of the training started with the introduction of Edison educational robots. The first week, more fun and easy applications were chosen to attract attention. The task of making the Edisons ready for use was given to the students, and then, by scanning the barcodes on the worksheets, the robots were made to perform applications such as avoiding obstacles, line following, and following the light. The researcher prepared 3 sumo wrestling tracks in A1 size, and students competed in sumo wrestling between groups as an end-of-lesson activity.

In the second week of the training, the Edware program was introduced, and Edison robots were started to be coded. The first activity, lighting and extinguishing the left LED, was demonstrated by the researcher on the smart board and also given in the students' worksheets. Then, the students were asked to turn on the right LED and solve the problem of alternately turning on and off the left and right LEDs. The activity of "beeping" with Edison robots was given to the students with the same logic, and they were expected to create their melodies. As an end-of-lesson activity, students were made to do a "speed game" activity with the robots' forward driving codes. This activity aimed to make students solve motion problems through robots.

In the third week, mBot robots were introduced to the students, and the use of the mBlock program was taught. With simple coding on the program, the robots were moved with the direction keys, and the use of card LEDs and buzzers was shown. The police car activity was made by following a specific algorithm (first, the right LED light red, then the left LED light blue), and the activity perception scale was applied at the end of the lesson.

In the fourth week, when Mbot doors were taught, the concept of sensors was discussed with the students, and a discussion environment was created by brainstorming about the sensors they encounter daily. "Robot Dancing in the Dark" with the light sensor and "Robot Avoiding Obstacles" projects were made with the distance sensor. Students were asked to give examples of daily life problems and to code robots to solve these problems.

In the last week of robotic coding training, mBot Led Matrix application was made. Students learned to use Led Matrixes and printed various shapes and writings on the leds. "Guard mBot" application was made by combining the information learned in the previous weeks. When all activities were completed, students were asked to complete the "Problem-Solving Inventory for Children." Finally, focus group interviews were conducted with the students.

***Data Collection Tools Used in the Research***

The study's quantitative data was collected through the "Problem-Solving Inventory for Children ". The "Problem-Solving Inventory for Children" used in this study was developed by Serin, Bulut Serin, and Saygılı (2010) to determine elementary school students' self-perception of problem-solving skills. The inventory consists of three factors and 24 items in total: "Confidence in Problem-Solving Skills" 12 items, "Self-Control" 7 items, and "Avoidance" 5 items. The factor analysis results calculated the inventory's total Cronbach Alpha reliability coefficient as 0.80. The test-retest reliability results of the inventory were 0.84 for the confidence in problem-solving skills factor, 0.79 for the self-control factor, 0.70 for the avoidance factor, and 0.85 for the total inventory (Serin et al., 2010). The scale was administered to the students before starting the activities and reapplied at the end of the 5-week training when all activities were completed.

Qualitative data were obtained through observation forms and focus group interviews. The researchers prepared observation forms and semi-structured questions. At the end of the lesson, the researcher formed groups of four to five people, and focus group interviews were conducted with 21 students.

***Data Analysis***

The analysis of the 3 research questions formed within the scope of the research was carried out in two parts: quantitative and qualitative. In the quantitative part of the study, the Problem-Solving Inventory for Children was applied and scored to investigate the effect of robotic coding education on students' problem-solving skills. The normality distribution of student scores was examined using the Shapiro-Wilks test. The reason for using the Shapiro-Wilks test as a normality test is that the group size is less than 50 (Büyüköztürk, 2012). According to the results, whether the analysis technique would be parametric or non-parametric was decided. For Confidence in Problem-Solving Skills among the sub-factors, the Paired Samples T-test, one of the parametric tests, and for the other score types, the Wilcoxon Signed Ranks test, one of the non-parametric tests, were used. The significance level was taken as 0.05 in all analyses.

In the qualitative part of the study, qualitative content analysis was used to analyze the data obtained through the interview method and observation forms. The primary purpose of content analysis is to reach relationships and concepts that can explain the collected data. Data that are similar to each other are brought together within the framework of specific concepts and themes, and these are interpreted by organizing them in a way that the reader can understand (Yıldırım & Şimşek, 2013). The data were analyzed by going through the stages of coding the data, finding themes, organizing the codes and themes, and defining and interpreting the findings.

For the data analysis, first, the audio recordings of the interviews with the students were transferred to documents with the help of a word processing program. The data obtained from the interviews were analyzed, coded, and grouped under appropriate themes. The themes and codes obtained were organized in tables, and student opinions coded as T1, T2... were included. The data obtained from the observation forms were reported in the same way. In addition, the researcher took short notes as a participant observer in the classroom during the five-week activities. At the end of the lesson, observation forms prepared by the researcher were filled in. The observations included notes on the problems, difficulties, and experiences that the students encountered during the activities. In addition, students' interest and motivation during the activities, changes in students' problem-solving skills, and technical problems encountered during the activities were also observed.

**FINDINGS**

This section presents the results of the data analysis collected within the scope of the research problem and sub-problems in tables. The findings obtained for the quantitative and qualitative parts of the research are discussed under separate subheadings. First, the findings are related to the quantitative part, and then the qualitative findings are reported. The normality of the data obtained from the research was examined, and the tests used in the analysis were decided.

***Findings Related to the Quantitative Section***

The pre-test post-test scale scores, and comparison results for the sub-factors (Confidence in Problem-Solving Skills, Self-Control, Avoidance) in the Problem-Solving Inventory in Children are presented.

**Tablo 2.** Paired Samples t-test results of test scores for the sub-factor of confidence in problem-solving skills

| Measure | N | $\bar{x}$ | S | sd | t | p |
|---|---|---|---|---|---|---|
| Pre Test | 26 | 43,46 | 7,89 | 25 | -9,04 | 0,000 |
| Post Test | 26 | 49,30 | 5,99 | | | |

It was found that there was a significant increase in students' confidence in problem-solving skills after the activities. While the mean score of students' confidence in problem-solving skills before the activities was $\bar{X}$ = 43.46, it increased to $\bar{X}$ = 49.30 after the five-week activities. This finding shows that the activities helped to increase students' confidence in their problem-solving skills.

**Table 3**. Wilcoxon Signed-Ranks test results of self-control sub-factor test scores

| Posttest-Pretest | N | Mean Rank | Sum of Ranks | z | p |
|---|---|---|---|---|---|
| Negative sequences | 1 | 3,500 | 3,50 | 4,213* | 0,000** |
| Positive sequences | 23 | 12,890 | 296,50 | | |
| *Equal* | *2* | - | - | | |

* Based on negative sequences
**p<0,05

According to the results of the analysis, it was revealed that there was a significant difference between the scores of the students participating in the study on the Self-Control sub-factor before and after the activities (z=4.213; p<0.05). According to the results obtained, it can be said that five-week robotic coding activities had positive effects on students' Self-Control sub-factor.

**Table 4**. Wilcoxon Signed-Ranks test results of avoidance sub-factor test scores.

| Posttest-Pretest | N | Mean Rank | Sum of Ranks | z | p |
|---|---|---|---|---|---|
| Negative sequences | 0 | 0,00 | 0,00 | 4,156* | 0,000** |
| Positive sequences | 22 | 11,50 | 253,00 | | |
| *Equal* | 4 | - | - | | |

* Based on negative sequences
**p<0,05

According to the results of the analysis given in Table 4, it was determined that there was a significant and positive difference between the Avoidance sub-factor scores of the students participating in the study before and after the activity (z=4.213; p<0.05). The pre-test Avoidance sub-factor measurement average is higher than the post-test Avoidance sub-factor measurement average. Table 5 shows the results of the pretest-posttest total score of the Self-Control sub-factor of the Problem-Solving Inventory.

**Table 5.** Wilcoxon Signed-Ranks test results of problem-solving inventory total scores

| Posttest-Pretest | N | Mean Rank | Sum of Ranks | z | p |
|---|---|---|---|---|---|
| Negative sequences | 0 | 0,00 | 0,00 | 4,463* | 0,000** |
| Positive sequences | 26 | 13,50 | 351,00 | | |
| *Equal* | 0 | - | - | | |

* Based on negative sequences
**p<0,05

When Table 5 was examined, it was found that there was a statistically significant change (z= 4.463; p<0.05) for the total score of the Problem-Solving Inventory from before to after the activities. In other words, it can be said that the five-week robotic coding training significantly and positively contributed to the students' problem-solving skill levels.

***Findings Related to the Qualitative Part***

For the data analysis, first, the audio recordings of the interviews with the students were transferred to documents with the help of a word processing program. The data obtained from the interviews were analyzed, coded, and grouped under appropriate themes. The themes and codes obtained were organized in tables, and student opinions coded as T1, T2... were included. The data obtained from the observation forms were reported in the same way. In order to learn the problems and difficulties encountered by the students in the robotic coding education and to examine the development of students' problem-solving skills in more detail, focus group interviews were conducted with the students at the end of the robotic coding education, and observation reports were kept every week. Observations were made using the observation form created by the researchers.

***Findings related to the interviews***

The findings obtained during the research process were evaluated under four categories. These were named "problem-solving skills," "problems experienced during the solution," "characteristics of the robotic coding education process," and "use of robotics in different courses." Five subcategories were formed under the problem-solving skill category: "understanding," "planning," "implementation," "debugging," and "revising." Table 6 shows the categories and subcategories with the number of participants in each category.

**Table 6.** Categories obtained as a result of the research findings.

| Categories and Subcategories | Number of Participants | Categories and Subcategories | Number of Participants |
|---|---|---|---|
| **Problem-Solving Skills** | | **Features of Robotic Coding Education Process** | |
| Understanding | 15 | Emotion states | 21 |
| Planning | 14 | Professional contributions | 6 |
| Application | 17 | Contributions to other courses | 5 |
| Debug | 21 | Problem-solving skills | 13 |
| Revision | 11 | | |
| **Problems During Resolution** | | **Use of Robotics in Different Courses** | |
| In-group problems | 4 | Numerical courses | 8 |
| Personal problems | 12 | Benefit | 8 |

The findings obtained during the research process are presented in line with the categories and subcategories of the research.

***Problem-solving skills***

Five categories were formed from the students' answers to the question, "Can you share with me the problems you experienced during the activities? How did you determine whether there was a problem while doing activities with robots?" Five categories were formed from their answers to the question. These categories are understanding, planning, implementing, debugging, and revising. Each category is analyzed and detailed separately.

The comprehension category was the stage in which the students determined whether there was a problem and what the problem was caused by. In this regard, students mentioned movement outside the codes and working differently from what was intended to be done. The movement outside the codes subcategory consists of 10 student opinions. The meaning of this category is that the robots coded in the program do not work as coded. Excerpts from student responses that can be given as examples for the subcategory of movement outside the codes are as follows.

> *S19: "When it does not work properly. By properly, I mean either it did not work from the beginning or it did something other than the codes I wrote."*

> *S18: "Teacher, if the robot does not work, if what is in the code does not match what the robot does, we have coded it to go forward, it goes left and right, or it rotates but does not go forward, it does not do what we want, then it is broken."*

Students performed various activities with the robots given to them during the five-week training. In these activities, students were given various tasks and asked to code their robots. If the robots did not exhibit the targeted behavior when they were operated, this was perceived as a "problem" by the students. For example, when they turned on the robot from the on/off button, the card leds lit up spontaneously, or the robot moved spontaneously. In such cases, the students stated that they tried to understand what the problem was in the robots. The following excerpts can be given as examples.

*S12: "...if it differs from what I want to do when I run the robot, then it does it."*
*S14: "Teacher, I do all the big things, but sometimes small things do not work. We know when something is wrong. We do it, it does not work as we want; it does not do what we want."*

The answers to the question "How do you go about solving your problem?" revealed the planning category. When the students explained what they did to solve a problem, the subcategories of mental design, sequencing, and choosing an appropriate method emerged. In the mental design subcategory, 7 students expressed opinions. Students stated that they thought about how to solve a problem and designed it in their minds. Quotations from students who expressed opinions in the mental design subcategory are below.

*S5: "...I follow the algorithm while turning on the robot, turning on the robot, checking the connection, I follow them. If there is a problem other than them, I make a plan in my head about how to solve it; then I solve it."*

*S20: "First, I check if everything is in order. If everything is in place, I try to do as you described. I build a path in my mind, and if I cannot realize that path, I build a path again and do it again."*

In making a plan, student 8 stated that they made a sequence to solve the problem. In these opinions gathered under the subcategory of sequencing, the students stated that they put a specific order in their minds to solve the problems they encountered and that they thought they could solve them in line with this order. The statements of S11 and S4, who expressed their opinions in the category of sequencing, are as follows.

*S11: "I look at the opening and closing, I look at the doors, as I said, I look at the serial port COM, so if there is a code before, I try to delete it, if not, I look at my codes."*

*S4: "First, I code them as 1,2,3 in my head, then I sort them and put them into practice."*

4 of the students stated that they looked for a solution to the problem while planning and that they tried to choose the most appropriate way by thinking about which one would work while choosing one of the solutions in their minds. The student statements that led to the formation of the subcategory of choosing the appropriate method are as follows.

*S9: "First, I look at the start of the opening key. Then I usually looked at the code or the door. Or I did it from the solutions you showed. I mean, well...it can change according to the problem of the robot."*

What the students said about what they did when they set out to solve the problem was grouped under the implementation category. The implementation category includes sticking to the plan, solving by coding, doing everything from the beginning, and trial and error. Six students said they tried to solve the problems per the plan they designed during the planning phase. The statements of S5 and S17 can be examples of the subcategory of sticking to the plan.

*S5: "First I understand the problem, I try to find out where the problem is. Then I create my plan about the problem, then I apply my plan exactly, and if it doesn't work, I go back to the beginning again."*

> *S17: "Teacher, we first identify that problem. So we plan it. Then we implement the plan and reach the result. If we cannot reach the result, that is, if the result is bad, if we cannot find it, we revise the plan again."*

Four students who thought that they could solve their problems by coding said that the first method they used to solve their problems was writing codes. One of the students, S14, stated, "At first, I correct the codes. For example, I code to turn off the lights if they are on." Some students said they did everything from the beginning to eliminate their problems. It can be said that these students had difficulties at the problem identification stage, so they took the methods that came to their minds from the beginning and applied them one by one. S3 summarized his opinion on this issue with the following sentence: "I take it from the beginning, that is, whatever we did at the beginning, I go from the beginning to the end". The statements of S18, one of the 3 students who aimed to find and solve the problem through trial and error, are given below.

> *S18: "Teacher, if the robot does not work, I first looked at the code. I tried to find the problem and solve that problem. Is there a problem in the cable, how can the problem be solved? We must have done something wrong, we will reach the right way by looking and trying. I do this until I find it, I eliminate what will not happen and do what will happen immediately."*

The last category under this heading is Debugging. This category's subcategories are coding errors, errors caused by robots, and solution sources. For the solution of their problems, the opinions of the students who stated that they tried to solve software errors were collected in the coding errors category. The students' opinions that they tried to solve the errors caused by the robots' hardware formed the categories of errors caused by robots. Whether the students received support while solving the errors that would solve the problems was handled in the solution source category. Seven students stated that they first updated the firmware while solving the problems they experienced in robots. Firmware update is a type of update made through the program for mBot, one of the robots used in the activities. The teacher applied this method many times to solve the software problem in the robot during the lesson. Mbot robots may have codes loaded from previous student uses stored in their brains. For this reason, it is an expected answer that the first application made by 7 students was firmware update. The statements of student S6 on this subject are given below.

> *S6: "I want to use the example of Mbot. When I connected the Mbot to the computer, it started to go straight once without pressing the codes. I did a firmware update without rewriting the codes and thus solved the problem."*

There were 10 students whose statements about coding errors were grouped together in the code control subcategory and 4 students in the connection control subcategory. The students in these subcategories stated that they tried to solve problems by performing operations on the programs they coded robots, checked whether they wrote the codes correctly, and performed operations to find deficiencies in the codes. They said that they performed operations to check the connections because the robots may experience disconnections while moving or the wrong serial port connection may be made. Sample quotations are given below for the code check and connection check subcategories respectively.

> *S1: "When I have such a situation, I first look at my codes because I am a distracted person. Because I may have dragged the wrong code. For example, the colors are the same in mBlock, for example, they can confuse me, I read them one by one..."*

> *S7: "I plug in the first cables etc. Of course, I always forget the connection COM3 COM4 and so on. When it doesn't work during the last run, I look at the top and see that the serial port is not connected. I make the connection again."*

The meaning of the solution source category is related to who or whom students get support from when solving a problem. The opinions collected in this category were grouped under three subcategories: self, teacher and friends. Six of the students stated that they tried to solve their problems by themselves until the end, and 9 of them stated that they tried to solve their problems with the help of their friends. 14 students formed the teacher subcategory by saying that they tried to solve their problems with the help of their teachers. Some students stated that they tried to solve the problem by themselves and got help from their teachers or friends when they could not. This situation caused some students to be grouped under more than one category. Student expressions related to the solution source category are given below under the subcategories of self, teacher, and friend.

> *S1: "Yes, I have had problems in general. When I can't solve it, I first start thinking about it myself, and then I prefer to consult you. I had a problem with mBot about connecting the cables incorrectly. But I solved it directly myself without contacting you."*

> *S2: "I came across mBot. It was not working, I mean, the wheel does not turn left and right. First I tried to solve it, and finally I applied to you. But I tried hard to solve it, I paid attention to the coding."*

> *S11: "Teacher, I did all of them with the help of my friend Hümeyra. Sometimes I solved some problems by doing it myself."*

Under the heading of revising, students' behaviors and thoughts when they struggled for a solution and could not reach a solution were discussed. Two categories were created under this heading. These were named as producing a new solution and returning to the beginning. Five of the students stated that they tried new ways to solve the problem when they could not, and six of them stated that they went back to the beginning and tried to solve the problem again. The student statements gathered under the category of generating new solutions suggested that the problem could not be solved because there was a mistake in the plan made for the solution, and therefore it was necessary to develop different solution strategies. S21 used the following expressions as an example for generating a new solution, and S17 used the following expressions as an example for the category of going back to the beginning.

> *S21: "I look for the solution elsewhere or try again. I mean, I may have made a mistake somewhere. I try to solve it with new plans by finding the place where I made a mistake."*

> *S17: "Again, we first identify the problem. So we plan it. Then we implement the plan and reach the result. If we cannot reach the result, that is, if the result is bad, if we cannot find it, we revise the plan again. We always go back to the first step like this."*

**Problems during resolution**

When the problems experienced by the students during the solution of their problems in robotic coding education were analyzed, two categories were formed. These categories were identified as in-group problems and personal problems. The students who were brought together in the category of in-group problems stated that their groupmate wanted to do his/her own way and made individual decisions. There are 4 student opinions in the category of in-group problems. The following excerpts can be given as examples of the in-group problems category.

> *S6: "I didn't have any problems with computers or robots, I only had problems in this regard because we were working in pairs and when I coded, my friend often deleted the codes and did it himself."*

> *S18: "Apart from that, when I was doing the coding, the friend next to me was coding and I was reading, and the friend next to me was making a mistake every once in a while, and I would say, "You are doing it wrong, you are doing it wrong," and he would deny it."*

The other category that emerged when the problems experienced during the solution were investigated was personal problems. During the activities, students mentioned problems such as forgetfulness while solving problems, thinking that they could not identify problems, wanting to work alone, being disturbed by the noise of the classroom, having a small glasses size, insufficient computer skills, fear of damaging robots, and carelessness. The 5 students who had forgetfulness problems stated that they usually forgot to turn on the robot. The following excerpt can be given as an example of the personal problems category.

> *S11: "Teacher, last week or what was it, there were robots and we were coding. We forgot to turn them on with Hümeyra. After that, the first thing we did was coding. I said to my friend, let's see if we had opened it, and we didn't open it. That's how it happened. We usually forgot."*

**Characteristics of the robotic coding education process**

As a result of the findings obtained from the interviews with the students, the title of the characteristics of the robotic coding education process emerged. Under this heading, the categories of emotional states, professional contributions, contributions to other courses, contributions to daily life and contributions to problem solving skills were created.

The emotional states category includes the subcategories of feelings during the activity and feelings of support. 9 of the students stated that they found the activities fun and 17 of the students stated that they enjoyed the activities. Students' favorite and most enjoyable applications vary, but in general, it can be said that there is a concentration on liking the activities with mbots and the edison sumo wrestling activity. Students used short expressions when expressing their feelings and did not give explanatory reasons. The following excerpts are examples of these categories.

> *S3: "I think everything was very fun."*

> *S2: "I think they were all good, teacher."*

> *S1: "Teacher, there was nothing that I did not like and did not have fun. Since we prevented the problems we encountered and solved them, they all ended in fun."*

> *S5: "What I like about it is that I have a lot of fun doing the activity and I want to do it again. What I don't like about it is that I agree with my friend, it would be better if we were alone in certain things. Some places need a group. So I liked it very much."*

The feelings and thoughts the students felt when they received help from their teachers or friends were given in the subcategory of feelings of support. In this category, 3 students stated that they were happy that their problems were solved. 3 students expressed sadness because they could not solve their problems without help. The students who could not solve the problem by themselves stated that in this case they might not have understood the subject and thought they had deficiencies. The 7 students who received help from others said that this situation provided learning for them and that they believed they could solve the problem themselves when encountering similar situations. The following excerpts can be given as examples of what is felt in the case of support.

> *S1: "When that happens, on the one hand, I am very happy, but on the other hand, because I cannot solve something very easy myself, I look at the robot again, I mean, I can do it too. Because usually in such situations, people have the capacity to solve it, but when they cannot use it, they may suddenly feel regret and unhappiness."*

> *S12: "While solving the problem, I try to apply a method that you or any other person has done, and I try to do it myself or try to find my own method."*

Questions were asked about what students gained from the robotic coding education, and the subcategory of professional contributions was formed based on the responses of 6 students. The students stated that their tendency to choose a profession was shaped by the robotic coding they learned in the training and that they thought that the information they learned here would benefit them when they chose a profession related to this field in the future. Some students say that they want to increase this knowledge in their future lives. In addition, it was also found that robotic coding education increased students' interest in technology and guided them in choosing a profession. The following excerpt may be an example of the subcategory of professional contributions.

> *S21: "I became more successful in the mBot by remembering the things we did in the previous weeks, for example, what I did in Edison. I may need that information for the profession I will choose in the future. Thanks to them, I can earn a good profession."*

> *S17: "Of course, I think what we learn here will be useful. For example, my teacher, you will be something in the technical industry, you need to know how robots work and how they are coded."*

The category of contributions to other courses was created in line with the statements indicating that the students thought that robotic coding education contributed to the information technologies and software course, science, and mathematics courses. There are 5 student opinions that led to the formation of this category. S4's statements can be given as an example for this category.

> *S4: "...teacher, when we code robots, there are operations in the codes. This goes into math. You need to adjust the degrees, speed, etc. It goes into science. Anyway, we will be coding in the informatics course and it will be useful there too."*

In the interviews with the students, the category of contribution to problem-solving skills was revealed in line with their approaches to problems and their thoughts during the five-week robotic coding activities. The students generally expressed their opinions about what they did when they had problems in the robotics coding course or in their daily lives. Thirteen of the students stated that they could look at problems from different perspectives, that when they encountered a problem, they first tried to find out what the problem was caused, and that they tried to develop specific strategies to solve it. The following excerpt can be given as an example for this category.

> *S15: "I put it in a sequence, teacher. First, I identify the problem, look at every part of it, for example, when an item breaks down. Then I identify all the things I can do about that problem. I try to do them and show what I cannot do to my mother or father. If they can't do it either, I take it to a mechanic."*

**Use of robotics in different courses**

The students were asked the question, "How would you like to use the materials you used in robotic coding education in other courses?" and the answers received from the students were grouped under the category of using robotics in different courses. The students who stated that the knowledge and skills learned during the activities during the robotic coding education process benefited their other courses said they would like to use robotic systems, especially for numerical classes. The statements of T2 and T8 among 8 students who expressed opinions about using robotic systems in numerical courses are given below.

> *S2: "I would like to use robots, teacher. For example, to solve problems in the mathematics course. We often solve problems in this course, and it also helps our mathematics. There are already operations in the codes. This goes into math. You need to set degrees and stuff like that, it's in science."*

> *S8: "I would like to, especially in mathematics, I would like operations and things like that, and I would like to in science because our subjects are heavier now, we cannot see the lessons practically, the elements and things like that. That's why I would like it."*

The reasons the students wanted to use robotic systems in other courses were investigated, and a benefit category was created. Considering the five-week training, the students stated that when they taught other lessons with robotic systems, they predicted that the lesson would be more fun, that they would be able to understand the lesson better, and that more manageable and more permanent learning could be achieved. The fun, better understanding, and facilitation subcategories emerged when the student responses were categorized according to intensity. 7 students said that it would be fun, and 4 students each said they would be able to understand better and facilitate the lessons. Excerpts that can serve as examples for these subcategories are given below.

> *S20: "I would understand more quickly because it was more fun. I would learn by playing and I would never forget it."*
>
> *S6: "I would like to use it in all lessons because it would make the lessons more fun. I would like it more, I would like to participate more in the lesson."*
>
> *S9: "Yes, I would because I would understand better and analyze better. I think it would be easier that way."*

**Findings related to the observation part**

The researcher took short notes as a participant observer in the classroom throughout the five-week activities. At the end of the lesson, observation forms prepared by the researcher were filled in. The observations included notes on the problems, difficulties, and experiences that the students encountered during the activities. In addition, students' interest and motivation during the activities, changes in students' problem-solving skills, and technical problems encountered during the activities were also observed.

**Condition of the observation environment**

Observer notes on the physical characteristics of the training environment are as follows:

"There are 26 students in the class, 8 females and 18 males. The classroom was organized by dividing the students into groups of two. The classroom is quite large, approximately 6 by 14 meters in dimensions. The classroom has four large windows that can provide sufficient light and ventilation. Since there are roller blinds on the windows, the blinds can be closed in case of light reflection on the smart board or when needed for some activities (such as a robot facing the light and dancing in the dark). There is one white whiteboard and one smartboard in the classroom. The walls are painted in a light color close to white. There are one-meter-high cabinets in the back of the classroom, and some of the projects students have done in other classes are on the cabinets. The classroom has 35 student seats and 3 fairly large desks. Sockets are fixed on the tables where computers can be plugged in. The teacher's desk and chairs are a little bit inside. That part is usually used for storing robots and computers. Every week before the students came to class, a computer, a mouse, and a two-person charger were prepared and placed on the student desks. Every week, spare robots, materials such as screwdrivers, batteries, 5 laptops, and mice were kept ready in case of possible situations."

**Technical problems experienced during events**

In the first two weeks, activities were done with Edison robots. Edison robots work with 4 AAA batteries. In the first week, the robots did not work correctly because the students could not insert the batteries correctly or read the barcodes backward. With the support of the educator, these problems were solved in a short time. The batteries running out quickly can be perceived as a problem. During the control-controlled driving phase, it was deemed appropriate to make separate matches with several controllers, as the interference of the control signals could cause problems. In the second week, when the Edison robots were coded, the program caused some issues. Although the EdWare program was installed on all computers before class, some computers had problems during coding. Using the online application was also impossible due to internet problems. Again, these problems were solved by the researcher and support teachers. However, this situation caused a waste of time. During the activities with mBot robots, some of the robots' wheels were broken when the students dropped them. In this case, spare mBots were used. The distance sensors of two mBots did not work; the replacement sensors were used in this case.

**Problems and difficulties experienced by students in the activity**

The worksheets prepared by the researcher for the students included instructions on installing the batteries. Despite this, most of the students had problems installing the batteries of the Edison robot. A few students worried about damaging the robots were observed in the first weeks. The researcher constantly reminded and encouraged the students that they should not be afraid of examining the robots, could easily remove and attach the cables to the robots, and could move them as they wished. In the third and fourth week activities, students often forgot to turn on the mBot and plugged the USB cable in the wrong place. Students also confused the door entries of the distance sensors from time to time. Similarly, in the third and fourth weeks, there were problems in making the connection and checking whether the connection was made. The students complained from time to time about the problem of attaching the wheels of the robots. Although the students were in a group with a friend of their choice, disagreements were observed in some groups. These problems were tried to be solved by changing the groups of students whose disagreements could not be resolved.

**Students' level of interest in the activities**

During the five-week training period, it was observed that students' interest and motivation in the activities were relatively high. In the first week's activities, the students' ability to activate the robots quickly without coding them with barcodes attracted their attention. In addition, the sumo wrestling races between groups at the end of the first lesson helped the students to mingle. They had a significant effect on their love for robotic coding education. The researcher deduced this result from the fact that the students did not want to finish the race even though the bell rang. The whole class was involved in this activity, which was asked to be done again in the following weeks. In the activities carried out with mBots, the concept of the sensor was asked to be discussed, and the students showed their curiosity and interest in the subject by giving examples of sensors and technologies they saw in their daily lives and their environment. The activities and projects the students were asked to complete were completed very quickly, and the sharing between friends has visibly increased in the last two weeks. The fact that the students were not absent during the robotic coding education and lined up in front of the class every week before the bell showed that their interest in the course was high.

**Students' problem-solving skills**

During the lessons, the researcher took notes on the students' problem-solving skills during the tasks assigned to the students and the realization of the activities. It was observed that students asked for help from the teacher for every problem they had, especially in the first three weeks, and reacted as "our robot is broken". This situation visibly decreased in the last two weeks, and students started to solve their problems independently. Students progressed in understanding their problems and finding the source of the problem. In the first activity, students generally focused on moving the robot by quickly passing the stage of understanding the problem and preparing a plan for the solution. However, in the following weeks, behaviors such as thinking longer about the problem, discussing it with their groupmates, and developing strategies about what can be done are noteworthy. Especially in the last training week, students tried to solve the problems themselves, received support from their friends when they got stuck, and finally preferred to seek teacher support. The main applications students use while solving problems are turning the robot on and off, checking the connection, updating the firmware, and checking the codes. It was observed that students generally found the correct method in the first weeks, primarily by trial and error and with the teacher's help. In the following processes, it can be said that students first tried to find the source of the problem based on their previous experiences and developed appropriate solutions for the problem.

**CONCLUSION and DISCUSSION**

According to the results of the Problem-Solving Inventory, administered as a pre-test and post-test to reveal the effect of robotic coding education on students' problem-solving skills, a significant and positive change occurred in students' problem-solving skills. The positive effect of robotic coding education on problem-solving coincides with the studies in the literature (Çavaş & Çavaş, 2005; Costa & Fernandes, 2005; Özer et al., 2017; Kırkan, 2018). According to the results obtained from focus group interviews with students, students thought that robotic coding activities contributed to their problem-solving skills. In addition, considering the students' statements in the interviews, it can be said that when they encounter an issue, they try to realize the stages of understanding the problem, preparing a plan, implementing the plan, and evaluating the results to a great extent. According to the researcher's observations, students improved their ability to cope with problems from the first week to the last week of the robotic coding training. While the first thing to do in the first activities was to get teacher support for the problems that arose, this situation decreased significantly, especially in the last two weeks. Students first tried to solve the problems they encountered or the problems given to them by themselves, helped each other with peer support in cases where it was not enough, and finally resorted to teacher support. This result is in line with the statements from the focus group interviews. Göksoy and Yılmaz (2018) and Oluk and Korkmaz (2018) found that robotic coding improved students' problem-solving skills. This situation overlaps with the findings obtained by the researcher from observations and interviews in this study.

It was tried to determine the students' likes and dislikes in robotic coding education, enjoyment of the activities, difficulties and problems, and experiences with robotic coding education. At the end of each lesson in the five-week training with the students, the activity perception scale was applied to the students. According to the data obtained from the scale, it was observed that almost all of the students found the activities enjoyable. The lowest perception score on the scale belonged to finding the exercise boring, and it was seen that the students did the activities without getting bored throughout the training. Observation and interview notes support this situation. Most of the students used the expressions "finding robotic coding education fun" and "liking the activities" in the focus group interviews. According to the researcher's observation notes and the responses from the scale, the students showed high interest and interest in the activities and especially enjoyed the activities in the race format. On the other hand, it was observed that the students were impatient to do the activities and wanted to finish the lecture part and start practicing immediately. This situation caused the researcher to have difficulty in explaining the subject from time to time. When the scores obtained from the items in the scale are analyzed, students think that the activities will benefit them and their lessons. The same findings were also observed in the interviews. Students mainly associated robotic coding with numerical courses and stated they thought it would contribute to information technologies and software courses. Studies emphasize that the use of robotic systems in numerical classes such as mathematics will positively affect the courses (Çorlu & Aydın, 2016; Williaams et al., 2008). Looking at the literature, another issue mentioned in student interviews is that robotic coding activities increase students' interest in technology and affect their career choices. Similar findings were also found in the research of Oluk and Korkmaz (2018).

**SUGGESTIONS**

Given these results, the following suggestions can be made to researchers and educators interested in the subject. Experimental studies with control groups can be conducted to investigate the effect of robotic coding activities on problem-solving skills. Robotic coding activities can be organized with Science and Mathematics teachers with the interdisciplinary understanding that STEM education aims. In the research, mentioning new technologies that will excite, intrigue, and motivate students before starting robotic coding activities may be meaningful. These technologies include 3D printers and studies conducted with printers, industry 4.0, artificial intelligence, makey makey, etc. Sharing pictures, videos, or sample designs of exciting projects that have been done or can be done with educational robots to be used in education with students before the activities helps students to attract their attention and gain different perspectives. Before starting the activities, it is necessary to ensure that the educational robots used in the activities are ready and that there are no technical problems. It is also recommended to pre-load and test the programs, if any, if a computer is used. A check can be made before the lesson for robots, tablets, etc., that run on batteries or rechargeable batteries.

In this study, students worked in groups of 2, and each group was provided with a robot and a computer. It is recommended to create such an organization for future studies. However, the point to be considered here is that the participants should be individuals who can get along with each other and have similar interests when forming groups. In addition, the fact that the study did not look at the group-based effect is a limitation. Conducting studies to determine the optimum number of groups may be recommended. Including end-of-course activities in education and organizing them in a competition format by forming groups of 5-6 students may motivate students with a sense of competition and affect their acquisition of skills such as collaborative work and leadership. Edison and mBot robots were used in this study. Similar studies can be conducted with different educational robots. This training is limited to 5 weeks of two hours per week. In future studies, the duration of the training can be increased, and more activities can be organized. Scientific studies investigating the effects of robotic coding education on students' creative thinking and collaborative working skills will contribute to the field.

**ETHICAL TEXT**

"In this article, the journal writing rules, publication principles, research and publication ethics, and journal ethical rules were followed. The responsibility belongs to the author (s) for any violations that may arise regarding the article. " Ethics committee approval was obtained from the Abant Izzet Baysal University Ethical Committee with the date 16.03.2018 and numbered 2018/102.

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