# The Effect of Robotic Programming Education on Learner's Critical Thinking Skills at The Secondary School Level

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**Abstract.** This study aimed to determine the effectiveness of robotic programming education on learner's thinking and critical thinking skills at the 6th-grade elementary school level. Student experiences were determined after each week. For this purpose, in the 2017-2018 academic year, four weeks of robotic programming training was applied to 20 students in the 6th grade of a public school in Uşak. The research was conducted by using video recording, critical thinking skill scales, and activity perception scales. At the end of the research, the findings obtained were included and suggestions were made for the inclusion of robotic programming in the education curriculum and the researchers and the application. In this study, one group pretest-posttest experimental model was used. In the analysis of quantitative data, a dependent samples t-test was used. As the process of adapting the perception of efficacy scale into Turkish was not fully concluded, the data obtained were interpreted on a substance-by-item basis. At the end of the study, a significant difference was found between the pre-test and post-test perception scores of the students in the experimental group. At the end of the activity perception scale, it was observed that students had positive experiences with robotic coding.

**Keywords:** Robotics programming, Critical thinking, STEM, Coding

## 1 Introduction

In a world where technology is at the center of our lives, the effectiveness of technology in the field of education has gradually increased and has led to the emergence of new needs in learning tools, learning objects and learning approaches. The boredom of traditional methods and textbooks, students' focusing problems in learning an abstract subject, their reluctance to learn new concepts, and their low participation in the lesson make it difficult to realize learning. An interesting activity in which students actively participate is effective in learning the lesson or subject. From this point of view, robotic tool sets can be used for an activity that is interesting for students and facilitates learning. The fact that robotic sets are cost-effective, have visual programming and less complex technology (components such as distance, light, touch sensors and

microchips) has enabled them to become educational tools that can be used in the classroom environment. Robotic toolkits are an application of the science of robotics, which is a sign of technological literacy [1], where many skills such as programming skills are gained through in class activities where robot behaviors such as moving the robot back and forth are programmed with Lego-like visual programming languages for children with their educational content. Robotic toolkits are educational materials in which students are fully involved, actively doing and actively thinking, their brains questioning and making connections. Each of the components of a robotics toolkit is connected to different fields of science. The components of a robot set are motor, sensor and program (coding). These parts depend on different fields of science such as engineering, electronics, computer science [2]. With robotics, students participate in science research through both technological design and computer programming activities [3]. Due to this interdisciplinary nature of robotic sets, when students learn how to build robots, they inevitably learn many other disciplines that robotics uses [4]. In 1998, the INFOESCUELA (ROBOTICA) project in 130 schools in Peru found that students who studied physics, mathematics, and programming principles using LEGO structures had a better understanding of these subjects, and that these students also improved their Spanish performance and showed higher self-esteem measures. These results show that the educational aspect of robotic tools is supported by research in the literature. The first example where robotic tools were used for educational purposes was Logo Turtles. Logo was originally developed for learning mathematical concepts, but it was also used as a thinking tool. Students were able to think about their own thinking, control and reflect on their work while solving the problem given to them. The activities carried out with robotic toolkits are also design activities. Design activities are activities in which students are active participants, they have more control over the learning process, interdisciplinary concepts are brought together, and pluralistic thinking is encouraged (suggesting that more than one solution and strategy is possible) [5]. Design activities engage people as active participants and give them a greater sense of control (and personal involvement) over the learning process [6]. Educational robotics offers a rich environment in terms of opportunities to integrate not only STEM but also many other disciplines, including literacy, social studies, dance, music and art, while giving students the opportunity to develop collaboration skills, express themselves using technological tools, find ways to work together to solve problems and think critically and innovatively [7]. Robotics can help make abstract concepts concrete. Because by programming the robot, the child can directly see the effect of the commands they write on the robot's actions [8]. Robotic vehicles can help children build personal relationships with ideas by using complex objects to introduce complex ideas in a concrete way. For example, the gears and motors of robotic vehicles can invite children to think about powerful ideas such as proportions [9]. Robotics activities should serve young people's different interests and learning styles [10]. Robotics realizes meaningful learning by providing opportunities for learning to be fun and enjoyable through the design and programming of robots. It also encourages students to actively participate in the learning process by supporting collaborative work. Students can creatively explore computer programming, mechanical design, physics, mathematics, motion, environmental factors and problem solving in a collaborative group environment [11].

## 2 Purpose of the Research

The aim of this study is to reveal the effect of robotic coding activities on critical thinking skills of middle school students. This research was conducted with Uşak Toki Şefkat Secondary School 6th grade students for 4 weeks within the scope of the Information Technologies and Software course. The study was conducted with a single group. There was no control group. Robotic education was applied to the group. Quantitative and qualitative data were obtained through pre-tests before the application and post-tests and video recordings afterward. By analyzing the data of various variables obtained from the experimental group, it was examined whether there was a significant difference in the critical thinking skills of the experimental group before and after the application. At the end of the research, answers were sought to the questions "Does robotic coding have an effect on students' critical thinking skills" and "what are students' perceptions about robotic coding".

After graduation, students should not only use technology comfortably but also be individuals who produce. Today, apart from basic literacy, the concepts of technology literacy and robotics literacy are becoming important. Robotics offers different types of learning opportunities such as encouraging peer social interaction, supporting creativity, social and cognitive development [12]. Robotics is a growing field with the potential to significantly impact the nature of engineering and science education at all levels, from K-12 to university level [13]. The studies on robotics in the literature are mostly related to the fields of physics and mathematics, and there are more studies indicating the importance of developing problem solving, logic and scientific inquiry skills with robotics [14]. More studies showing that it has positive effects in different disciplines should be conducted. Considering the studies in the literature, robotics activities provide environments where students are active, participate in the learning process by collaborating with their peers, and construct knowledge themselves. There are studies showing that the learning outcomes obtained through robotics activities have positive effects in many areas such as the development of programming skills, the development of skills in this field by understanding mathematics-engineering concepts more easily, critical thinking, and the development of higher-order thinking skills. This research is important in terms of presenting findings on the effect of robotics, which has been popular in recent years, on critical thinking skills. In addition, the findings on critical thinking skills were supported by the thinking skills and activity perception scale.

### 2.1 Assumptions

In this research, students gave sincere answers to the scales applied, it is assumed that the sample determined for the research represents the population.

### 2.2 Limitations

The sample of this research is limited to 20 students studying in the 6th grade in a secondary education institution affiliated to the Ministry of National Education within the borders of Uşak City Center. The findings of the study are limited to the Critical

Thinking Skills Scale, video recording, and the Activity Perception Scale. The duration of the research is limited to a 4-week training period. Limited to 1 robot kit and 1 computer. It is limited to the demonstration teaching technique. Limited by the absence of a control group.

# 3 Conceptual Framework

With the increasing popularity of robots, robotics has become an innovative approach in the field of educational technology and has been used in many educational levels from kindergarten to university. The theoretical basis of robotic kits is based on Seymour Papert's constructivism theory and its use in education started in the 1960s with Papert's Logo (programming language) Turtle (robot). Lego/Logo is a material where design activities can be done in the classroom, that is, students design their own machines with Lego parts consisting of motors and sensors and write a computer program to control the machine. Robotics is promoted in many schools as an innovative learning environment for developing higher-order thinking skills and abilities and helping students solve complex problems [15]. Robotics is seen as an effective problem-solving tool where students will be exposed to real-world problems. Students can improve their problem-solving skills in robotics-based learning environments. The task of teachers here will be to try to apply the problems that students can relate to the real world in the best way in robotics lessons [16]. Robotics is a pedagogical tool to teach the basic concepts of math and science in today's test-based education environment imposed on K-12 teachers. When we list the reasons for the use of robotic kits, we can see that robotic kits are a learning object that positively affects learning and motivation [19], [17] it is a learning object that teaches how all parts of a system interact with each other [18], [19] it is a learning object that positively affects learning and motivation by using motors, sensors, computer programs while using robotic kits. When the literature on the use of robotic kits as educational tools was examined, studies that increased students' technological knowledge and programming skills [20] and obtained positive results for learning scientific knowledge and mathematics concepts were found more frequently

## 3.1 Critical Thinking

It is known that Socrates first used the concept of critical thinking in 600 BC and defined it as "evaluating something with its good or bad sides". In literature, it is defined as a reflective and logical (rational) thinking [21] that focuses on deciding what to believe or what to do. Today, it has become important for students to learn to think, to have thinking skills, and to graduate from school as individuals who produce and criticize in order to be successful in business life. Critical thinking is an important and necessary skill because it is a mandatory skill in business life. Critical thinking is a mental process that people use to solve problems, make decisions and learn new concepts [23]. Schafersman (1991) argues that education consists of communicating two different things to students: first, the subject matter of the course or the content of the discipline ("what to think"), and second, the correct way to understand and evaluate

this subject matter ("how to think"). He stated that the content of the relevant disciplines is effectively conveyed to students, but often we do not teach students how to think effectively about this subject matter, that is, how to understand and evaluate it correctly, and he called this second ability critical thinking. In this context, critical thinking is an integral part of education [24]. Therefore, critical thinking is a skill that should be taught in school. Critical thinking can be taught to people of all ages [25] and it is the teacher's responsibility to evaluate critical thinking as an output in the context of education. The acquisition of critical thinking skills in the school environment is the responsibility of the teacher and is a learning situation that needs to be supported by the curriculum and learning materials. Research on critical thinking has found that technologically rich school environments have a positive effect on developing this skill. For example, in a study suggesting that schools should incorporate technology into all learning areas in order to develop students' higher order thinking skills, he stated that students with better information processing skills scored higher in critical thinking activities [26]. In another study, it was mentioned that robot building involves encountering real-world problems, multidisciplinary teamwork, creative and critical thinking [27]. Therefore, examining the effect of robotic coding on critical thinking skills constitutes the main problem of this study.

## 4 Method

In this study, it was aimed to determine the effect of robotic coding activities on critical thinking skills of middle school students. For this purpose, the study was conducted on 6th grade students of a secondary school affiliated to the Ministry of National Education within the scope of Information Technologies and Software course in the 2017-2018 academic year. In this study, a single group pretest-posttest experimental model was used. The reason for choosing this model is that research permission could be obtained for a single group. The research design is given in Table 1.

**Table 1.** Research Design

| Group | Pre test | Process | Post test |
|-------|----------|---------|-----------|
| G | $O_1$ | X | $O_2$ |
| | Critical Thinking Scale (Depending variable) | 4 weeks (Robotic Training) | Critical Thinking Scale (Depending variable) |

The experimental application was carried out over a 4-week period. Robotic training and the application of the scales were carried out by the researcher. The implementation process of the research is given in Figure 1.
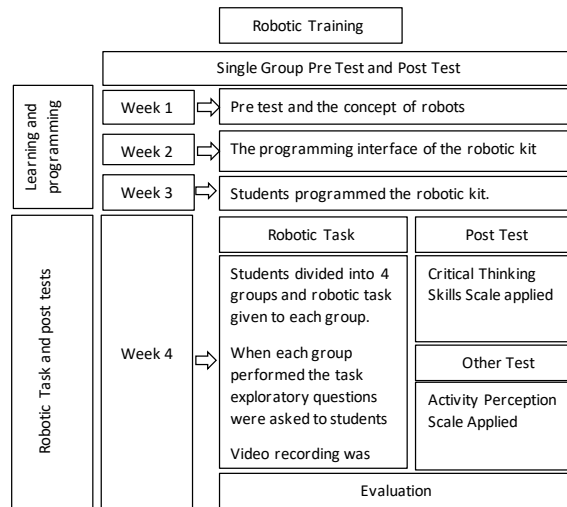
**Fig. 1.** Implementation process of the research

Qualitative data were collected at the end of the study to support the quantitative data obtained during the experimental implementation process. For this purpose, the experimental group students were given a robotic task and their thinking skills were measured. In addition, student experiences were tried to be determined at the end of each activity. The study group of this research consists of Uşak Toki Şefkat Secondary School 6th grade students (n=20) affiliated to MoNE. The research was conducted with a single group. Demographic information of the study group is given in Table 2.

**Table 2**. Demographic information of the study group

| Class Level | Gender | |
|---|---|---|
| | Girl | Boy |
| 6 | 9 | 11 |



**Fig. 2.** Students working as a group during a robotic coding activity

## 4.1  Design of The Teaching Process

In this study, the 5-step model developed by Duron et al. [28] was used in the design of the course to direct students to critical thinking.

They defined a 5-step framework that can be applied in almost any educational environment for teaching critical thinking skills effectively. They stated that this framework can be used to lead to a more active learning environment that is more enjoyable and effective for both teachers and students. According to this model, the higher-order thinking skills that students should acquire (estimation, observation, manipulation, computation) were determined. Robotic activities that would encourage students to learn effectively were selected. Appropriate questions were asked to students while they performed robotic tasks.
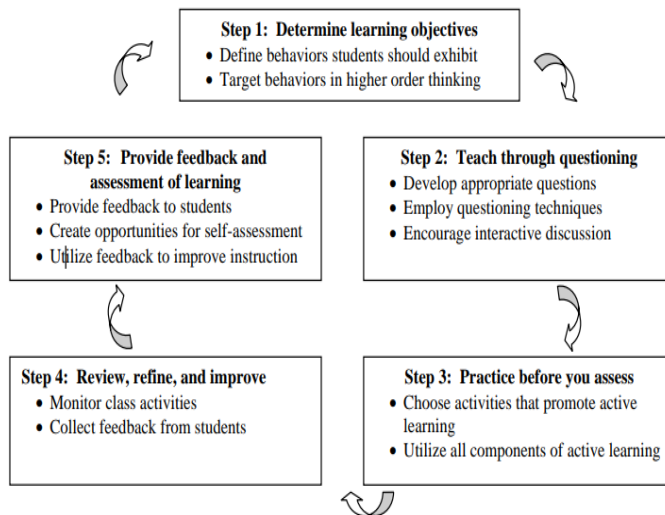
**Step 1: Determine learning objectives**
- Define behaviors students should exhibit
- Target behaviors in higher order thinking

**Step 5: Provide feedback and assessment of learning**
- Provide feedback to students
- Create opportunities for self-assessment
- Utilize feedback to improve instruction

**Step 2: Teach through questioning**
- Develop appropriate questions
- Employ questioning techniques
- Encourage interactive discussion

**Step 4: Review, refine, and improve**
- Monitor class activities
- Collect feedback from students

**Step 3: Practice before you assess**
- Choose activities that promote active learning
- Utilize all components of active learning

**Fig. 3.**  5 Step Framework

Robotic activities have 2 stages. The first stage is learning and programing the robotic kit, and the second stage is having the robot perform a determined behavior (robotic task). The first phase took place in 3 weeks and the second phase in the last week. The robotic training was organized around 3 main objectives: (i) getting to know the robot and its parts (O-bot robot kit, sensors, programming board); (ii) working with the robot kit (collecting data from the environment with sensors and using the programming interface); (iii) making the robot kit perform a certain task (such as following a black line). Since there was only one robot kit, students were trained in groups with the researcher. One robot kit and one computer were used. The outcomes targeted during the training are given in Table 3.

**Table 3.** Gains

| Robotic coding Week 1 | Examples of robots used in daily life are given. It is ensured that the concepts related to the robot are discovered by the student himself (concepts such as motor, sensor, etc.). Students describe the robot |
|---|---|
| Robotic coding Week 2 | Students recognize the O-bot robot kit. Students Recognize the idea interface used to program O-bot. Students download and install the Idea program on the computer. Learn the concept of sensors. Recognizes the Idea Control card. Programs o-bot. |
| Robotic coding Week 3 | Students attach the parts that will enable the robot to move for a certain task. Students install sensors that will enable the robot to collect information from the environment for a specific task. Studets programs the robot kit. Students experiment with the operation of the robot in a real environment. In the program code of the robot, it makes predictions on the values that should change according to the situation in the virtual environment and in the real environment. In case the robot does not work, it reviews and corrects the program. |
| Robotic coding Week 4 | Students attach the parts that will enable the robot to move for a certain task. Students install sensors that will enable the robot to collect information from the environment for a specific task. Studets programs the robot kit. Students experiment with the operation of the robot in a real environment. In the program code of the robot, it makes predictions on the values that should change according to the situation in the virtual environment and in the real environment. In case the robot does not work, it reviews and corrects the program. |

In the first week of the activity, direct expression method and question and answer technique were used. "The students were asked what comes to their mind first when they think of robots and their answers were taken. Then they were asked to give examples of robots used in daily life. Students generally gave examples of humanoid robots. Students were asked "What makes the robot move? How do robots collect information from the environment?" and they were asked to make their own definitions of what a robot is and what systems it consists of. In the second week, the researcher explained how they could build a robot (motor, sensor, programming, etc.) using the show-and-do method. In the third week, under the guidance of the researcher, programming was done using the robot kit and 1 computer. Red and blue leds were connected to the robot kit and the program that allows these leds to blink for a certain period was written and uploaded to the robot kit. In the fourth week, the students were divided into groups and asked to "build and program the robot to stop at a certain

distance from the obstacle" under the guidance of the researcher. After the students did the programming, they were asked "what kind of changes they should make in the programming in case the distance of the robot to the obstacle increased" and they were asked to reprogram accordingly. No time limit was set for the groups to complete this task. The groups were asked to express aloud "what they did and why they did it" while performing this task. Some groups had the opportunity to observe their robots by changing the values of the variables after completing their robots collaboratively. Due to time constraints, some groups could not make changes in their coding and observe the results. They could only fulfill the robotic task given to them. Only students in one group were able to complete the robotic task with the guidance of the researcher.

## 4.2   Data Collection Tools

During the data collection phase of the qualitative dimension of the study, video recordings were taken to determine thinking skills. Detailed information about the relevant data collection tools is presented in this section. In this study, critical thinking skills were tried to be measured both qualitatively and quantitatively in two ways. The perception scale for critical thinking was used as the first method and the 4-dimensional coding key, which is a sub-dimension of critical thinking, used by Sullivan in his study, was used as the second method. With the activity perception scale, it was tried to determine student experiences towards the robotic activity. The transcript process of the conversations recorded on video by the researcher was done in the Nvivo program. A video coding key was created by the researcher and the data were analyzed with the Nvivo program in line with the criteria determined. Once a video or audio recording has been made, the first step forward is a content coding key or content list. The content coding key is best done immediately after the recording or as soon as possible, because the researcher's memory is still fresh and this allows for explanations of events that may not be possible later [29]. In order to develop critical thinking, the researcher asked questions to the students during the video recording such as "how should the coding be for the robot to stop at 5 m distance?", "what will we stop if the distance is less than 5?", "why do we do the coding this way?". The students were randomly selected and divided into 4 different groups and a coding key was created to show how they used their thinking skills in solving the robotic problem given to them. The coding key was used in a way that Sullivan [30] took directly from the national science education standards of AAAS (1993) and NRC (1996) [31]. Table 4 shows the coding scheme.

**Table 4.** Coding scheme

| Skill | Type of Skill | Description of Code |
|---|---|---|
| Observation | Thinking | Student observes the execution of an algorithm by the robotic device, or the results of a measurement with a sensor. |
| Evaluation of Solution | Science process | Student makes an evaluative comment about the solution. |
| Estimation | Thinking | Student makes estimations regarding timing and speed variables included in her solution. |

| Hypothesis generation | Science process | Student generates an idea about why the robotic device is not functioning properly, based on observation of the functioning of the robot. |
|---|---|---|
| Hypothesis testing | Science process | Student tests the hypothesis he has generated. |
| Control of variables | Science process | Student changes only one element of a program at a time when testing a hypothesis. |
| Manipulation | Thinking | Students use available tools to take measurements for use as variable modifiers in solving robotics challenges. |
| Computation | Thinking | Students use mathematical operations to assist in solving the problem. |

## 4.3 Critical Thinking Scale

The 5-point Likert-type Critical Thinking Skills Scale in the questionnaire form developed for young people between the ages of 12-18 was examined by an academician and researcher and translated into Turkish and applied. This scale named "Critical thinking in daily life" consists of 20 items. The internal consistency value between the scores given to the scale was examined and Cronbach's alpha value was calculated as 0.87. There are different reports on acceptable values of alpha, ranging from 0.70 to 0.95. Accordingly, the reliability of the scale is high. The scale was designed in 5-point Likert type and the scale's ratings are "Never: 1", "Rarely: 2", "Occasionally: 3", "Frequently: 4" and "Always: 5".

## 4.4 Perception of Eddectiveness Scale

The "Activity Perception Scale", which was translated into Turkish by Kasalak (2017) and is available in English in the literature in order to determine student experiences related to robotic coding activities, was applied. The findings obtained from the activity perception scale applied at the end of each activity were interpreted. The scale consists of 11 items. The scale is designed in 5-point Likert type and the scale is graded as "Strongly disagree: 1", "Somewhat agree: 2", "50%-50%: 3", "Strongly agree: 4" and "Strongly agree: 5". The items adapted into Turkish were analyzed by two academicians and two teachers. As a result of the evaluations, it was predicted that only 11 items of the 25-item scale would be correctly understood by the 5th grade students in our country due to the differences in cultures and educational systems, and the scale was finalized [32].

## 4.5 Implamentation Process

First, before starting the experimental study, the pre-test to be applied to the group was determined and adapted to Turkish. Then a lesson plan covering 4 weeks was prepared. The activities prepared for the lesson were turned into presentations. In line with the studies in the literature on group work [33], in which robotics offers a collaborative and

fun environment, is successful in teaching basic programming concepts, and teachers are successful in providing a collaborative and creative environment, groups were formed in this study The O-bot robot kit used in the application process is programmed with idea, an algorithm development and visual programming software with a Turkish interface. After the program is installed to O-bot even with a USB cable, the robot can work independently from the computer. O-bot robot kit is given in Figure 5. This kit consists of O-bot carrier platform (the platform where parts such as Idea control card, sensors, wheels are combined), idea control card (programs written in the idea environment are loaded and run on the idea control card, which can be defined as a minicomputer. Idea software development environment allows algorithm development with visual programming. Idea software environment is in Turkish. The robot kit is programmed using the Idea interface. Flowcharts are used while programming. Flowcharts created using Idea software constitute visual programming. Idea software environment is given in Figure 3.
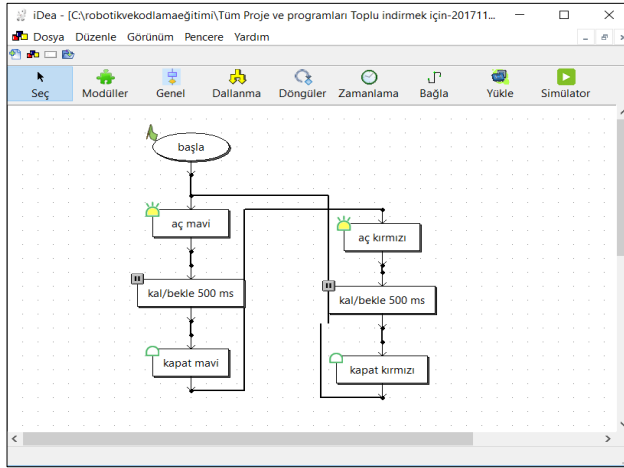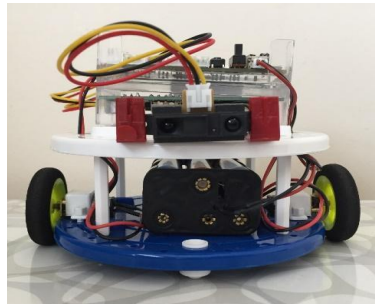


**Fig. 4.** İdea software environment.


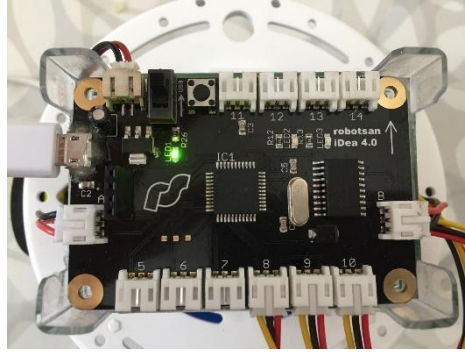
**Fig. 5.** Robotsan o-bot robot kit

**Fig. 6.** İdea control card

Robot Simulator: The algorithms developed by Robotsan in the idea environment can be tested in a virtual environment with the ideasim robot simulator and observed whether they work or not. Idea Simulation environment is given in Figure 7.
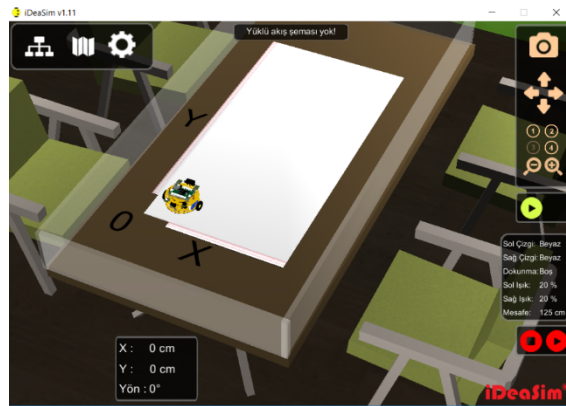


**Fig. 7.** İdea simulation environment

## 4.6  Analysis of Qualitative Data

The critical thinking skills of the experimental group (one group) were examined with the quantitative method. SPSS 22.0 software was used in the statistical analysis of quantitative data. The 5-point Likert-type critical thinking skills scale in the questionnaire form developed by Mincemoyer, Perkins and Numyua [40] for young people between the ages of 12-18 was entered into the Spss program. Since the missing data were random, there were not many losses and the sample size (n=20) was small, it was filled with serial average in the SPSS program. After determining that the data had a normal distribution, the dependent samples t-test was applied. The dependent samples t-test is a parametric test used to test the statistical significance of the difference

between 2 means obtained from two related samples. By checking the assumptions of the independent samples t-test, it was seen that the difference scores between the measurements of the continuous variables were normally distributed. After checking the assumptions, a dependent samples t-test was applied to examine whether robotic coding training had a significant effect on critical thinking skills. The effectiveness perception scale was applied to students after each weekly robotic activity. The effectiveness perception scale, adapted to Turkish by Kasalak [32], was developed by Deci, Eghrari, Patrick, and Leone [41] for uninteresting (boring) computer tasks in the literature. Since the adaptation process of the effectiveness perception scale to Turkish was not fully completed, the data were analyzed item-by-item. The data belonging to the effectiveness perception scale were analyzed with the SPSS Statistics 22 program and the data were interpreted according to the Effectiveness Perception Scores Mean and Standard Deviation Values.

### 4.7 Analysis of Quantitative Data

To reveal the effect of robotic coding on critical thinking, critical thinking skills were tried to be measured in two ways. For this purpose, critical thinking skills were supported with qualitative data. In this research, the data obtained by video and formed in line with the coding key were analyzed with the computer-aided qualitative data analysis program Nvivo (QSR NUD * IST (Non-Numerical Structured Data Indexing Search and Theorizing). The data obtained within the scope of this research were interpreted by showing them graphically. After opening the Nvivo 12 Pro software, the videos were imported into the program from the Import tab. The transcript process of the video files was done using the Nvivo software interface. An example of video transcript process is given in Figure 8.
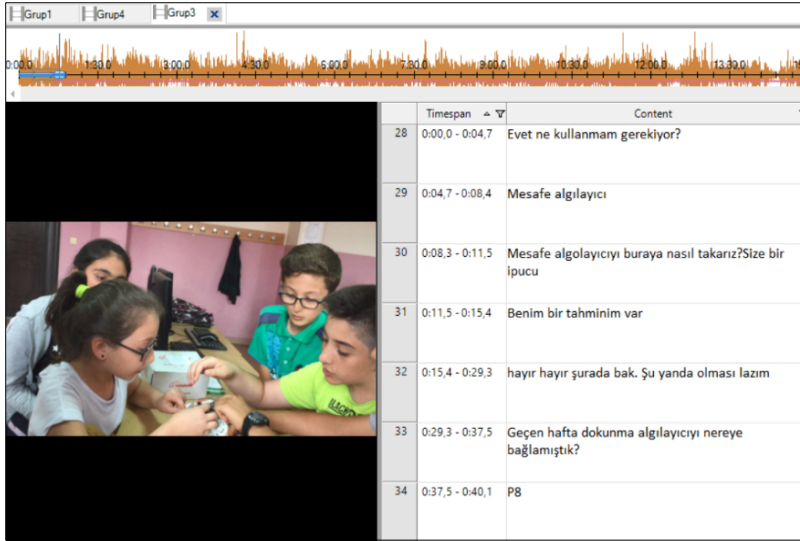


**Fig. 8.** Example of video transcript process

An illustrative example of one of the groups is given in Table 5 to show how the students used their thinking skills while solving the robotic problem (stopping the robot when it was a certain distance away from the obstacle) in the last week. The use of each skill was labeled in the Nvivo program according to the coding key. For example, the sentence "we will connect the sensor with the apparatus" was coded as "manipulation" in the Nvivo program. For the coding to be done in this way, students were asked to express their thoughts aloud.

Nodes (Codes) were created before the analysis of the videos and the speech texts were coded with the drag and drop method. Codes are a representation of thinking skills. The coding made by creating nodes in the Nvivo Pro 12 program is given in Figure 9. After the coding process, the data was visualized and interpreted.
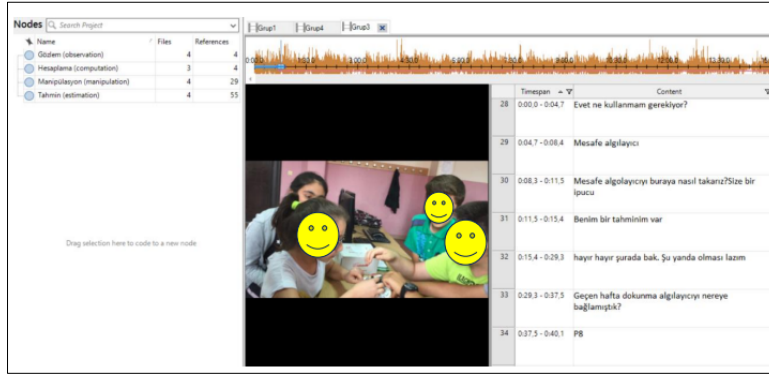


**Fig. 9.** Nvivo Pro 12 Nodes (Codes)

**Table 5.** Example coding of video files

| Skill | Type of skill | Description of student's activity |
|---|---|---|
| Observation | Thinking | Students started the robot and observed that the robot stopped when the distance was less than 5 |
| Manipulation | Thinking | Only one of the students knew the correct place to attach the sensor from the picture projected on the screen by the researcher and attached it. The other students thought that they would choose the input used for the touch sensor they used in the previous week's application. Another student connected the sensor to the relevant place with the apparatus and realized that the direction of the sensor was reversed. |
| Estimation | Thinking | The students realize that they put the batteries in incorrectly. They then operate the o-bot as they programmed it. One connected the o-bot to the computer with a usb cable. The program gave a warning saying please add a distance sensor |

| | | |
|---|---|---|
| | | module. The researcher reminded the students that they had not introduced the distance sensor and asked them where to connect the distance sensor. |
| Computation | Thinking | This skill was not used. |

# 5  Findings

The findings obtained from this study are given under three headings: "findings related to critical thinking skills", "findings related to thinking skills", and "findings related to finding the robotic activity fun".

## 5.1  Findings of Critical Thinking Skills

Before the experimental process, a dependent samples t-test was applied to examine whether robotic coding training had a significant effect on students' critical thinking skills. Assumptions were checked first. The skewness and kurtosis coefficients were examined to determine whether the difference between the pre-test and post-test scores showed a normal distribution, and the descriptive statistical results of these scores are presented in Table 6.

**Table 6.** Descriptive statistics results for the difference between pre-test and post-test scores of critical thinking skills

| Measurement | $X$ | Ss | Min | Max | ÇK | BK |
|---|---|---|---|---|---|---|
| Difference | 4,65 | 12,399 | -14 | 33 | 0,578 | -0,125 |

When the skewness (SD) and kurtosis coefficients (SD) were analyzed, it was seen that they showed normal distribution. After the assumptions were checked, the scores of the experimental group on critical thinking skills were compared with the dependent samples t-test. The results of the analysis are presented in Table 7.

**Table 7.** Dependent  Samples t test results

| Measurement | N | $X$ | Ss | t | $\eta2$ |
|---|---|---|---|---|---|
| Pre test | 20 | 75,08 | 11,16 | - | 0,14 |
| Post test | 20 | 79,74 | 9,45 | 1,68[*] | |

*p<0,01

Dependent samples t-test was applied to compare the pre-test and posttest scores of the students in the experimental group (Table 8). Accordingly, a significant difference was found between the scores. [t(19)=-1,68, η2=0,14, p<0,01]. Students' perceptions after the experiment (X̄=79,74, Ss=9,45) increased compared to before (X̄=75,08, Ss=11,16) Robotic coding instruction had a large and positive effect on critical thinking and explained 14% of the total variance. According to the dependent samples t test result, it can be said that robotic education has a positive effect on critical thinking skills.

## 5.2 Findings on Thinking Skills

In order to examine the effect of robotic coding training on students' thinking skills, groups were given robotic tasks and videotaped while performing this task. First, the videos were transferred to the Nvivo 12 Pro program and the transcription process was performed. The coding process was then performed, followed by the matrix coding query process. Matrix coding query in NVivo is particularly functional in terms of querying possible relationships between the characteristics of the cases included in the research (called demographic variables in quantitative research terminology) and the categories you created or coded during the analysis [42]. In this context, the use of thinking skills according to groups was questioned (Figure 10).
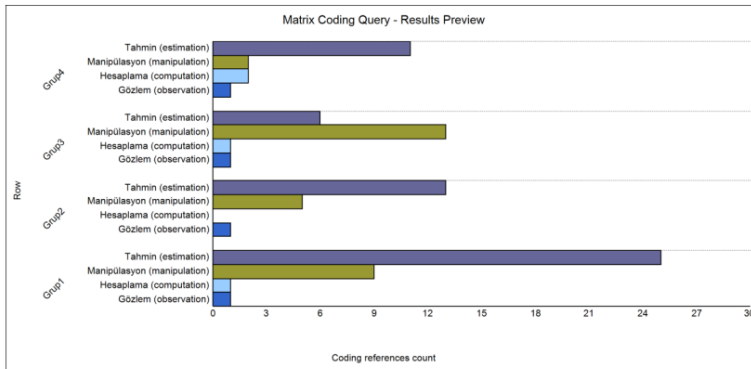


**Fig. 10** Usage rates of skills for all groups

According to these results, estimation skill was used the most by Group 1, and manipulation skill was used the most by Group 3. Group 2 did not use computation skill during the robotic task given to them. Observation, manipulation and estimation skills were used by all groups. Accordingly, it can be said that robotic coding training had a positive effect on students' use of thinking skills.

## 5.3   Findings Related to Robotic Activity

The data of the effectiveness perception scale were analyzed with SPSS Statistics 22 program. The scale was evaluated on item basis. The mean and standard deviation values of the scores obtained from this scale are given in Table 8.

**Table 8** Mean and Standart Deviation values for finding the robotics activity fun

| Articles | Week 1 | | Week 2 | | Week 3 | | Week 4 | |
|---|---|---|---|---|---|---|---|---|
| | $\underline{X}$ | Ss | $\underline{X}$ | Ss | $\underline{X}$ | Ss | $\underline{X}$ | Ss |
| It was fun to do this activity | 4,50 | 1,00 | 4,83 | .48 | 4,62 | .73 | 4,88 | .44 |
| I believe this event is important for my development. | 4,50 | .88 | 4,57 | .67 | 4,30 | 1,06 | 4,67 | .73 |
| I had a lot of fun doing this activity | 4,65 | .58 | 4,73 | .54 | 4,56 | .66 | 4,78 | .52 |
| I think it was a really important event | 4.45 | .75 | 4,67 | .56 | 4,25 | .89 | 4,62 | .80 |
| I did this activity because I wanted to do it | 4,15 | 1,34 | 4,45 | 1,04 | 3,96 | 1,53 | 3,85 | 1,59 |
| I think it was a very boring event | 1,88 | 1,44 | 1,48 | .99 | 1,61 | 1,21 | 1,53 | 1,14 |
| I would like to do this activity again as I think it was useful. | 4,07 | 1,27 | 4,77 | .52 | 4,36 | .85 | 4,62 | .74 |
| I believe that doing this activity can be useful for me. | 4,49 | .98 | 4,42 | .99 | 4,34 | .91 | 4,47 | 1,04 |
| I believe this activity can help me do better at school | 4,17 | 1,18 | 4,37 | 1,08 | 4,39 | 1,08 | 4,67 | .65 |
| I thought it was a very interesting event | 4,37 | 1,03 | 4,77 | .52 | 4,50 | .98 | 4,62 | .58 |
| I would like to do it again as there are some things that this event gave me | 4,47 | 1,04 | 4,57 | .87 | 4,14 | 1,29 | 4,77 | .52 |

Regarding the 4-week activity, it is seen that the average score given to the item "doing this activity was a lot of fun" was 4.50 at the lowest and 4.88 at the highest. The lowest mean score for the item "I had a lot of fun doing this activity" was 4.56 and the highest was 4.78. It is seen that the lowest score given to the item "I think this was a very boring activity" is 1.48 and the highest score is 1.88. This table shows that students'

perceptions of finding the robotic coding activity fun are quite high. It is seen that the mean scores given by the students to the items related to their perceptions of activities related to their personal development vary between 4.07 and 4.77. It can be stated that the effect of the robotics activity on students' personal development is positive and high. It is seen that the mean scores they gave to the item "I believe that this activity can help me do better at school" varied between 4.17 and 4.67. Accordingly, it is seen that the belief that robotics education can help students to be more successful at school has increased.

## 6  Discussions

Within the scope of this study, robotic programming training was given in the sixth-grade information technologies and software course and the effect of this training on students' critical thinking skills was examined. In addition, at the end of each application, the activity perception scale was applied to determine student experiences related to robotic activities. According to the results of the pre-test and post-test critical thinking skills scale, students' perceptions after the experiment increased compared to before. It was concluded that robotic coding instruction had a large and positive effect on critical thinking. While the students performed the robotic task in groups, they programmed the robot as they were taught and did not develop their own strategies to solve this problem. Nevertheless, they tried to solve the mistakes they made while programming the robot through trial and error. In this context. In this study, it can be said that the collaborative working environment has a great effect on the development of critical thinking. Research on the flowchart used in the problem-solving process has shown that it is a tool that helps in the development of understanding and decision-making processes and the development of critical thinking skills [34]. It can be said that the flowchart used in this study also improved students' critical thinking skills. In addition, it can be said that the use of the skills used in Sullivan's [30] study, which is a sub-dimension of critical thinking, including 4-dimensional robotic tasks, by all of the groups (only the calculation skill was not used by one group) had a positive effect on critical thinking skills. In another study in the literature, at the end of the analysis of a study in which students were asked to solve a robotic task and think aloud by explaining what they did and why, it was stated that the complex robotics-based learning environment, which requires the use of problem-solving and critical thinking skills, requires high-level cognitive and meta-cognitive thinking skills such as programming for the movement of the robot, continuous situational awareness and decision-making strategies [35]. When looking at the studies in the literature, it has been seen that robotics is an interdisciplinary learning method that includes critical thinking [43] and is a technology-supported learning tool that allows students to work collaboratively. As in this study, in the studies in the literature, in order to support collaborative learning in the course design, students were given robotic tasks in groups of 2 or 3 and finally a final project was requested from the students [44]. The duration of the studies in the literature is longer than this research. For example, the studies were spread over a longer period of time over 6 weeks [39], 14 weeks [45], a semester [44]. Although this study was completed in a 4-week period, it gave results consistent with

many studies in the literature. The results of this study are consistent with Liu et al.'s [39]. They showed that critical thinking ability improved after 6 weeks of robot programming learning. In order for students to use their thinking skills effectively while performing the robotic task, they should be given the opportunity to work with the robot kit for a longer period of time. It is important that students have time to observe different results by trial and error both during the coding and designing of the robot kit. The length of time spent in a technology-rich learning environment has a positive, nonlinear effect on the development of critical thinking skills [36]. In this context, it is seen that the necessity of longer time is also supported in the literature. It was aimed to determine student experiences related to robotic coding education by applying the activity perception scale. With this scale, it was concluded that the students' perception of finding the robotic coding activity fun was quite high, the effect on their personal development was positive and high, and the belief that robotic education could help students do better at school increased. In addition, the fact that students found the robotic activity fun had a positive effect on their motivation and increased their participation.

# 7   Conclusion

In this study, it was examined whether there was a significant difference in the critical thinking skills scores of the group given robotic programming training before and after the experiment. In addition, students' perceptions were tried to be determined by applying the activity perception scale after each activity. It was concluded that the effect of robotic coding on critical thinking skills was positive. Although the use of robotic kits in the classroom environment does not give definite and guaranteed results, it has a positive effect on improving students' educational experience. A robotics-based learning approach is very promising because of its immediate/constructive feedback in a problem-solving situation. Such problems have shown positive results in various problem-solving skills [38] such as critical thinking. In such robotic activities, students need more time to use different strategies in problem solving skills and accordingly develop higher order thinking skills. The limitation of this study is the lack of time. As a result, it was seen that students enjoyed the robotic coding activity, found these activities fun, and had a positive effect on their critical thinking skills. In this respect, it can be said that the educational aspect of robotic kits is rich.

# 8   Recommendations

The results of the research are presented below under two sub-headings: "Recommendations for Practice" and "Recommendations for Research".
   Robotic activities can be done as group work. The number of kits to be used in robotic activities can be adjusted so that each group has 1 kit. In this study, robotic activities were conducted with 6th grade students. A longer study can be conducted at a different grade level. It was observed that some students were not active during group

work. Students' interests can be identified in advance and robotic activities can be designed accordingly. During this study, it was observed that some students had difficulty in programming their robots. For this reason, these students should be given easier robotic tasks that will allow them to succeed. Considering these students, graphical programming with an easy-to-use interface can be selected. Groups that successfully complete robotic tasks can be encouraged to see how they can solve the same problem in a different way. In this study, the robotic kit attracted the students' interest and activities can be organized to support different disciplines by using this motivation. Robotic tasks should be completed over a longer period. In this way, students can overcome the mistakes made by trial and error and observe different results by manipulating the values of variables during coding.

It is important how teachers present robotic activities to students, which tasks to set and which classroom interaction to encourage. After providing students with knowledge of robots and robotic technology, especially knowledge and skills that increase learning can be gained through robotic behaviors. Studies on robotics-supported teaching methods can be conducted on teacher trainings. If how to use robotic kits will be taught in the education to be given within the scope of the research, a robotic literacy scale can be developed. Curriculum studies including robotic coding activities can be conducted. When selecting robot kits to be used in the classroom, attention should be paid to hardware features. Robotics research can be conducted on various student groups (different academic level, ethnic group, gender). Robotic applications related to the development of digital age skills can be done. At the end of the research, students' own opinions about robotics can be taken

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