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The Effect of STEM-Based Robotic Coding Education on Primary School Students' Decision-Making Skills

STEM Temelli Robotik Kodlama Eğitiminin İlkokul Öğrencilerinin Karar Verme Becerileri Üzerine Etkisi

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ABSTRACT: The aim in this study was to determine the effectiveness of STEM-based robotic coding education for primary school students in terms of their decision-making skills. Mixed method research was conducted. Pretest–posttest control group designs were used in the quantitative phase, and a case study was performed in the qualitative phase of the research. The study sample consisted of 65 third graders. Pretesting of the experimental and control group students was performed using the decision-making skills scale. STEM-based robotic coding training was given to the experimental group for 6 weeks. Afterwards, the decision-making skills scale was applied as a posttest to both the experimental and control groups. The quantitative data were analyzed with paired and independent samples t-tests. A statistically significant increase was observed in the experimental group students' decision-making skills in favor of the posttest. There was no significant difference between the pre- and posttest scores of the control group students. An interview with 15 experimental group students was conducted to collect qualitative data, and the interview results were analyzed using content analysis. The robotic coding education positively affected the students' decision-making and problem-solving skills and their willingness to share ideas.

Keywords: Decision-making, mixed method, robotic coding.

ÖZ: Bu çalışmanın amacı STEM temelli robotik kodlama eğitiminin ilkokul öğrencilerinin karar verme becerisi üzerine etkisini incelemektir. Araştırmada karma yöntem tercih edilmiştir. Araştırmanın nicel aşamasında ön test- son test kontrol gruplu desen, nitel aşamasında ise durum çalışması deseni kullanılmıştır. Araştırmanın örneklemi ilkokul üçüncü sınıfta öğrenim gören 65 öğrenciden oluşmaktadır. Deney ve kontrol grubundaki öğrencilere karar verme beceri ölçeği ön test olarak uygulanmıştır. Ardından altı hafta süre ile deney grubuna STEM temelli robotik kodlama eğitimi verilmiştir. Uygulama sonucunda ise hem deney hem de kontrol grubuna karar verme beceri ölçeği son test olarak uygulanmıştır. Nicel veriler t testi tekniği ile analiz edilmiştir. Nicel verilerden elde edilen bulgular deney grubu öğrencilerinin karar verme becerilerinde son test lehine artış olduğunu ve bu artışın istatistiksel olarak anlamlı olduğunu göstermiştir. Kontrol grubu öğrencilerinde ise ön ve son test puanları arasında anlamlı bir farklılık görülmemiştir. Nitel verilerin toplanması amacıyla ilgili eğitimi alan 15 öğrenci ile üç sorudan oluşan yarı yapılandırılmış görüşme yapılmıştır ve görüşme sonuçları içerik analizi tekniği ile analiz edilmiştir. Nitel verilerden elde bulgulara göre robotik kodlama eğitimi öğrencilerin karar verme, problem çözme ve fikirlerini paylaşmaya dair süreçlerini olumlu yönde etkilemiştir.

Anahtar kelimeler: Karar verme, karma yöntem, robotik kodlama.

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Teaching educational disciplines through an integrative approach rather than teaching them separately has gained importance in recent years (Sickel, 2023). STEM education, which is one of these integrated teaching approaches, refers to an interdisciplinary approach in which the aim is to acquire 21st century skills (Topsakal et al., 2022), such as problem-solving (Çakır & Altun-Yalçın, 2021), creativity, decision-making (Pleasants et al., 2019), and entrepreneurship (Meral and Altun-Yalçın, 2022). In addition, it is seen that STEM education, which involves teaching by integrating science, technology, engineering, and mathematics, is integrated with different teaching practices.

Thibaut et al. (2018) have categorized the themes in which STEM education is integrated, namely STEM content-based integration, problem-based integration, research-based integration, design-based integration, and teamwork-based integration. The content-based category includes instructional practices for making connections between different STEM disciplines. In other words, it is related to the interdisciplinary role of STEM, which includes solving daily life problems. Further, in this category, the focus is on curriculum-based issues, the integration of technology, and the teaching of concepts and skills belonging to certain disciplines (Hwang & Taylor, 2016). In the problem-based integration category, there are problem-based learning and project-based learning and focusing on real-life problems. In research-based integration, there is integration with practices that encourage students to research, such as data interpretation, questioning, and authentic scientific process practices. Design-based integration includes engineering design practices, learning from failure, and schematic solutions. Teamwork-based integration, as its name suggests, supports collaborative learning, communication, and working in small groups (Thibaut et al., 2018).

The increasing importance of technology integration in education has resulted in robotic coding education becoming widespread (Altun Yalçın et al., 2020). Thus, it is seen that STEM education has been integrated into robotic coding education in recent years. This progress in today's technological age has caused robotics to become popular at almost all educational levels (Seckin Kapucu, 2023). The dissemination activities related to robotic coding are carried out via the courses and training given to teachers and students entitled "robotic coding" (Çınar, 2020; Filipov et al., 2017).

Robotics constitutes a broad section covering concepts related to mechanical materials, motors, sensors, and programming (Rogers et al., 2010). Coding refers to a process by which a computer, electronic circuit, or mechanical device carries out a series of instructions (Güven et al., 2022). Accordingly, educational robotics can be described as the process of introducing robotics and related topics within the knowledge set of a specific curriculum content acquired by a student; it can also be explained as the addition of robotics and its entire background to a certain curriculum (Patiño-Escarcina et al., 2021).

Text-based and block-based programming are both options for students to code. Using a computer keyboard, students create codes and commands as text according to text-based coding procedures. Block-based coding, on the other hand, consists of combining blocks like a jigsaw puzzle without writing any text (Güven et al., 2020).

In general, studies on the robotic coding applications in education have put more emphasis on the effects of educational robotics on cognitive domains of individuals, such as problem-solving, computational thinking, creativity, STEM skills, metacognitive skills, and transferring skills (Anwar et al., 2019; Zong and Xia, 2020). It has been shown in many studies that robotics education contributes to these cognitive skills (Tramonti et al., 2023). However, the skills investigated within the scope of robotic coding are not limited to the cognitive domain. In addition to cognitive skills, there are studies investigating affective domain and social skills such as collaboration, communication, motivation, and attitude (Yang et al., 2023). In these studies it is also argued that robotic coding contributes to affective domain skills, social skills, attitudes, and motivation (Atman-Uslu et al., 2022).

It is essential to emphasize the incorporation of robotic coding into education to promote its widespread acceptance. Robotic coding has been integrated into courses, curriculum content, and various disciplines such as mathematics and technology (Bers et al., 2019; Alqahtani et al., 2022). In addition, studies in which robotic coding is integrated with STEM have gained importance in recent years. Kaygısız et al. (2020) carried out a study on the teaching of STEM-based robotic coding applications with the participation of prospective primary school teachers and, according to the result of their study, prospective teachers can basically integrate robotics into STEM-based science teaching. Moreover, preservice teachers stated that robotics might be included in all guides, particularly science, and this could make a contribution to students' algorithmic thinking abilities and problem-solving. Tiryaki and Adıgüzel (2021) found STEM-based robotics applications increased the creativity and scientific attitudes of secondary school students.

Research problem

Considering the studies carried out in the field in question, it can be asserted that the experimental studies on STEM-based robotic coding are quite limited. The field of educational robotics requires more experimental studies, according to Tselegkaridis and Sapounidis (2022). Their research indicates that nonexperimental methods are favored by most researchers, which highlights the need for a shift in research practices. By utilizing an experimental design, the present study can make a valuable contribution to the field. Additionally, the study's focus on decision-making skills is a unique aspect that sets it apart from other research in the field. As mentioned above, the experimental studies were mostly focused on students' cognitive domain skills. These skills particularly emphasize computational thinking, creativity, critical thinking, and problem-solving. On the other hand, one skill important for students to acquire from an early age is decision-making. Children's decision-making skills continue to develop due to the fact that their brains are still maturing (Garon and Moore, 2004). Decision-making is unique to humans, who have reason, logic, consciousness, and will, and all human actions are related to a decision-making process (Yurtseven et al., 2021). A person has to encounter a series of situations in which the obligation to make a decision arises. The decision-making process consists of different elements such as defining the problem in the face of any event, creating options for the defined problem, choosing the most appropriate one among all the options, making a decision according to the plans made, implementing the decision, and evaluating the result (Adair, 2000). These stages are very similar to problem-solving, the engineering design process, and STEM implementation processes (Meral et al., 2022). For this reason, it is hypothesized that STEM-based robotic coding education can influence students' decision-making skills.

While studies, such as that by Agostini et al. (2017), indicate a positive impact of robotics on decision-making skills, there is a notable absence of experimental research addressing the relationship between STEM-based robotic coding and these skills. Therefore, it is considered that the present research will make a contribution to the field, due to its investigation of the effect of STEM-based robotic coding on students' decision-making and the inclusion of primary school students, contrary to the general trend in related studies. In this regard, the objective was to determine the impact of STEM-based robotic coding education on primary school students' decision-making. Aligned with this purpose, the aim in the research was to provide answers to the following research questions:

1. Does STEM-based robotics coding education have a significant impact on primary school students' decision-making skills?
2. Does STEM-based robotics coding education have a significant impact on the subdimensions of decision-making skills of primary school students?
3. What are the viewpoints of primary school students concerning STEM-based robotics coding education?

Method

Research Design

The sequential explanatory mixed method was used in the research. This design was chosen to investigate the efficiency of the research, to explain the results with different measurement tools, and to test its reliability. In this method, quantitative data are dominant and collected beforehand; then qualitative and quantitative data are analyzed. The experimental design was chosen in the quantitative phase of the research. Findings obtained in the quantitative method are presented as numerical data and analyzed using statistical methods (Büyüköztürk et al., 2008). A pretest–posttest paired control group model was used in the quantitative stage. The case study design and the semi structured interview method within this scope were included in the qualitative stage. Semi structured interviews allow the participants to describe the world they perceive with their own thoughts through open-ended questions prepared in advance by the interviewer (Patton, 2014).

Study sample

The study universe comprised primary school students, and the sample consisted of 29 third graders in the control group and 36 third graders in the experimental group. Convenience sampling, which is categorized as a nonprobability sampling method, was chosen because of the proximity and easy access to the sample (Etikan et al., 2016).

Table 1

Study Sample

		N	Grade
Control group	Pretest	29	3rd grade
	Posttest	29	3rd grade
Experimental group	Pretest	36	3rd grade
	Posttest	36	3rd grade

Ethical Procedures

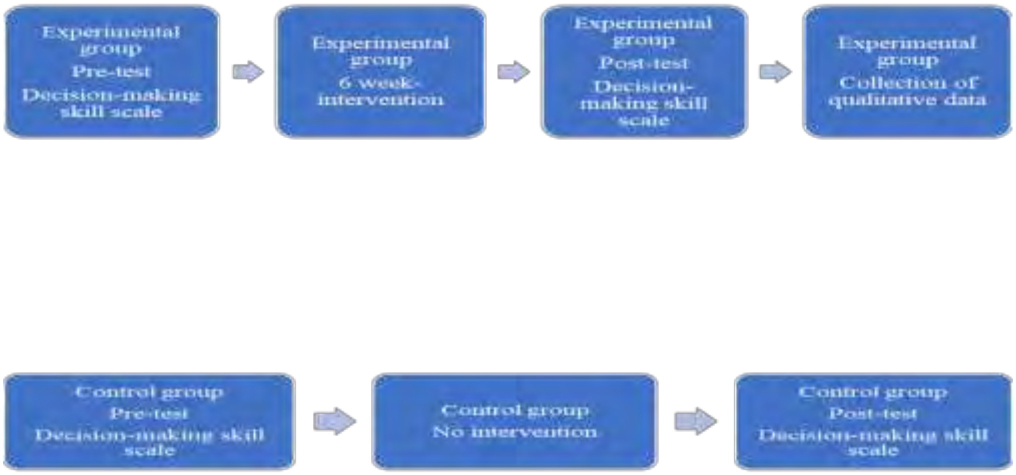
Ethical approval with the number 01/10 (31.01.2023) was obtained for the study from the university's scientific research and ethics committee where the research was carried out. The informed consent process was meticulous, with participants and their parents receiving detailed explanations of the study's procedures and data usage. Participant consent was acquired verbally and in writing, and volunteers were carefully selected. In addition, parents' written approval was acquired and submitted as part of the application to the ethics committee. The participants were informed of their right to withdraw from the study at any time. To prevent bias, the data were transcribed verbatim as reported by the participants. Pseudonyms were assigned to the participants to maintain confidentiality. The research was carried out systematically. The data were collected transparently and honestly through audio recording methods.

Implementation

Both the experimental and control group students completed a decision-making skill scale before the application, and the experimental group underwent a 6-week STEM-based robotics training program. Afterwards, the same scale was applied to both groups. As part of the experimental procedure, STEM-based robotic coding training was offered to 36 third grade students for six weeks. The training was provided using Lego-based Fischertechnik sets. The students performed these activities in groups. Figure 1 illustrates the stages of the application process.

Figure 1

The Application Process of the Research



Experimental Intervention Process

In the initial step, the students were divided into 3 to 4 groups. Fischertechnik construction kits were allocated to each group. Subject matter experts were present within each group to guide the students. Subsequently, the students undertook the task of crafting prototypes for engineering designs employing the building blocks provided. Noteworthy examples included prototypes for a traffic light, a carousel, a washing machine, and automated gate and exit control systems such as barrier gates commonly encountered in various settings.

Following the prototyping phase, the students proceeded to encode and execute the functionalities of these structures. The expert instructors performed an observational role, offering each student a distinctive problem scenario for coding and scrutinizing the accuracy of the code composition. Finally, all group members collectively engaged in higher-order thinking, deliberation, and collaborative coding endeavors. Consequently, each student was allowed to contribute to individual coding pursuits, thereby collectively addressing the challenges encountered. In addition to providing the students with hands-on coding experience, this approach also facilitated collaborative problem-solving within the group.

Data Collection Tools

A decision-making skill scale was used to collect quantitative data from the students. It was a 5-point Likert-type scale consisting of 17 items. These 17 items contained a total of 5 subdimensions: realizing and identifying a problem, gathering information, generating alternative options, decision-making, and implementing and evaluating the decision. The scale, which was created by taking account of the opinions of 12 experts, was developed by Demirbaş Nemli (2018). The CVR (Scope Validity Criteria) formula was applied for each item in calculating the validity rate of the scale. According to this formula, items with a CVR coefficient below 0.56 were eliminated.

Since the chi-squared value in Bartlett's test was significant, the next step was taken. In the next step, Kaiser–Meyer–Olkin (KMO) analysis was performed, which showed the KMO coefficient to be 0.876. As this coefficient approaches 1, the scale is considered suitable for analysis. In the next stage, factor analysis was performed and it was seen that the data obtained explained 55.177% of the population and this value was sufficient for the scale to be usable. The reliability Cronbach alpha value for the whole scale was 0.781. An interview with a semi-structured format was carried out with 15 experimental group students after the application to collect qualitative data. Three questions, which were about the processes of decision-making, were asked during the course of the interview.

Data Analysis

The Shapiro–Wilk and Kolmogorov–Smirnov tests were utilized to examine the normality of the quantitative data and, according to the results, the data showed a normal distribution. Subsequently, the t-test, a parametric test, was performed to analyze the quantitative data. The pre- and posttest means of both the experimental and control groups were analyzed with the paired samples t-test. Afterwards, the experimental and the control groups were analyzed among themselves with the independent samples t-test.

The kurtosis/skewness values and Shapiro–Wilk and Kolmogorov–Smirnov test results of the normality distribution analysis are shown in Table 2.

Table 2

Normality Test Results of Quantitative Data

Groups		N	x̄	SD	Shapiro–Wilk	Skewness	Kurtosis
Control group	Pretest	29	2.984	0.354	0.488	-.002	-.823
	Posttest	29	2.911	0.339	0.438	-.417	-.225
Experimental group	Pretest	36	2.721	0.412	0.321	-.497	0.751
	Post test	36	3.403	0.304	0.038	-.840	0.276

Table 2 shows the normality test results of the pre- and posttest scores of the control and experimental group. Based on the Shapiro–Wilk results, since the sample number was below 50, except for the experimental group's posttest Shapiro–Wilk value, the other values are above 0.05 and show a normal distribution. Since the kurtosis/skewness value of the experimental group in the posttest was between -2 and +2, the entire dataset is normally distributed (George & Mallery, 2010).

The qualitative data of the research were examined by content analysis. This is a technique that aims to intensify the phenomenon and obtain a broad definition of it. As a result of the analysis, concepts or categories that define the phenomenon are created. Content analysis allows the researcher to examine the data via an impressionistic, instinctive, and interpretive approach (Hsieh & Shannon, 2005).

Validity and Reliability

The necessary information was given to the students at the beginning of the research to provide validity of the quantitative stage of the research and it was ensured that the students consciously answered the questions on the scale. The application time was not kept too long to minimize the effect of subject loss and subject maturation. Attention was paid to ensuring that the scale applied to the students was appropriate for their level. In addition, Cronbach alpha reliability analysis of the currently valid and reliable scale was also performed. The Cronbach alpha values obtained in the present study were 0.782 for the control group pretest, 0.740 for the control group posttest, 0.734 for the experimental group pretest, and 0.751 for the experimental group posttest. The results of the scale are considered reliable provided that the Cronbach alpha value is above 0.70 (Taber, 2018). Furthermore, students must give sincere answers to ensure the validity of the qualitative stage of the research (Büyüköztürk et al., 2008). For this reason, sufficient time was provided for the interaction with students. Moreover, codes and categories were confirmed by both experts and participants through direct quotations. The reliability formula (Reliability: Consensus/(Consensus+Disagreement)×100), which was created by Miles and Huberman (2014), was used to determine the reliability of the qualitative data. The agreement between the codes and categories, which were developed by two separate researchers who are experts in their fields, was calculated according to this formula. The reliability coefficient was 92%.

Results

Quantitative Data

The quantitative results are presented in Tables 3-6.

Table 3

Paired Samples t-test Results of the Control and Experimental Groups

Groups		N	x̄	SD	t	p
Control group	Pretest	29	2.984	0.354	0.879	0.392
	Posttest	29	2.911	0.339		
Experimental group	Pretest	36	2.721	0.412	-7.348	0.000
	Posttest	36	3.403	0.304		

*p>0.05, * *p<0.05

The paired samples t-test results of the pre- and posttest means of the control and experimental groups are presented in Table 3. It is seen that there is no statistically significant difference between the pretest mean (x̄=2.984) and the posttest mean (x̄=2.911) of the control group (p>0.05). However, there is a statistically significant difference between the pretest (x̄=2.721) and posttest (x̄=3.403) means of the experimental group in favor of the posttest (p<0.05).

Table 4

Results of the Paired Samples t-test for the Subdimensions of the Control Group

Subdimension	Measurements	N	x̄	SD	t	p
Realizing and identifying a problem	Pretest	29	3.034	0.667		
					0.306	0.762
	Posttest	29	2.982	0.604		
Gathering information	Pretest	29	3.506	0.465		
					0.646	0.524
	Posttest	29	3.419	0.581		
Generating alternative options	Pretest	29	2.738	0.579		
					-1.747	0.093
	Posttest	29	3.007	0.633		
Decision-making	Pretest	29	3.043	0.653		
					5.093	0.000
	Posttest	29	2.087	0.570		
Implementing and evaluating the decision	Pretest	29	3.095	0.654		
					-.183	0.857
	Posttest	29	3.131	0.640		

There was no significant difference between the pre- and posttest means of the control group in any of the four subdimensions ($p>0.05$), namely realizing and identifying the problem, gathering information, generating alternative options, and implementing and evaluating the decision. On the other hand, a significant difference was observed in favor of the pretest in the decision-making subdimension ($p<0.05$).

Table 5

Results of the Paired Samples t-test for the Subdimensions of the Experimental Group

Subdimension	Measurements	N	x̄	SD	t	p
Realizing and identifying a problem	Pretest	29	3.034	0.667		
					0.306	0.762
	Posttest	29	2.982	0.604		
Gathering information	Pretest	29	3.506	0.465		
					0.646	0.524
	Posttest	29	3.419	0.581		
Generating alternative options	Pretest	29	2.738	0.579		
					-1.747	0.093
	Posttest	29	3.007	0.633		
Decision-making	Pretest	29	3.043	0.653		
					5.093	0.000
	Posttest	29	2.087	0.570		
Implementing and evaluating the decision	Pretest	29	3.095	0.654		
					-.183	0.857
	Posttest	29	3.131	0.640		

According to Table 5, the pre- and posttest means of the four subdimensions of the experimental group differ significantly in favor of the posttest ($p<0.05$). These subdimensions are realizing and defining the problem, generating alternative options, decision-making, and implementing and evaluating the decision. However, no significant difference is observed between the pre- and posttest means of the subdimension gathering information ($p>0.05$).

Table 6

Independent Samples t-test Results of the Control and Experimental Groups

Groups		N	x̄	SD	t	p
Control group	Pretest	29	2.984	0.354		
					-.276	0.785
Experimental group	Posttest	36	2.721	0.412		
Control group	Pretest	29	2.911	0.339		
					0.581	0.285
Experimental group	Posttest	36	3.403	0.304		

The independent samples t-test results of the pre- and posttests of the control and experimental groups are given in Table 6. According to these results, there is no statistically significant difference between the pretest means of the control group (x̄=2.984) and the experimental group (x̄=2.721) ($p>0.05$). In addition, there is no statistically significant difference between the posttest means of the control (x̄=2.911) and the experimental group (x̄=3.403), although the posttest score of the experimental group is higher ($p>0.05$).

Qualitative Data

Content analysis techniques were used to analyze the qualitative data, which are shown in Tables 7, 8, and 9 along with the frequency and percentage values.

Table 7

Students' Views on the First Question

Category	Code	Frequency (F)	Percentage (%)
Yes	Placement of Lego blocks	8	38
	Wrong coding	5	24
	Communication with friends	5	24
No	Not encountering a problem	3	14
Total		21	100
Solutions	Getting help	9	50
	Trying different alternatives	6	34
	Communication solutions	3	17
Total		18	100

Table 7 shows the answers to the question "Did you encounter problems while doing robotic coding activities? How did you solve the problems you encountered while doing these activities?" Accordingly, only 3 out of the 15 students stated that they did not encounter any problems at all. These students stated that the robotic coding activities were easy and they could perform them without any help. On the other hand, other students (80%) encountered some problems. The main problem encountered by the students concerned the placement of Lego blocks (38%). The students had problems while attaching the blocks to each other or they set them incorrectly. In addition, they encountered an error in coding (24%). Some students (24%) had problems in communicating with their group mates. For instance, these students stated that they had disagreements with their group mates in deciding on how to code. According to the category of solutions, half of the students (50%) found solutions to their problems by getting help. They solved their problems by asking questions to their teachers and asking friends for help. Some students tried to come up with a solution by trying different alternatives (34%). For instance, when they incorrectly set the blocks, they tried to attach them in a different way or they tried to complete their models by trying different tools. Some students, on the other hand, preferred to solve their problems by talking to their friends (17%). In this way, they found solutions to their communication problems.

S1: "I solved my problems by asking my teacher for help." S2: "I got help from my friends in solving my problems."

Table 8

Students' Views on the Second Question

Category	Code	Frequency (F)	Percentage (%)
Yes	Learning how to do	12	53
	Learning from mistakes	4	15
	Learning from ideas	2	8
	Placement of Lego blocks	3	11
	Problem-solving	2	8
	Being sure	1	4
No	No impact	1	4
	Not getting along with friends	1	4
Total		26	100

Table 8 presents responses to the question "Did these activities contribute to your decision-making skills? Why or how?" along with the categories and codes. A significant majority of the students (92%) stated that the robotic coding activities contributed to their decision-making skills. In this case, the most frequently stated reason (53%) for this contribution was because robotic activities contributed to students learning how to code and considering it. Additionally, some of the students (15%) discovered that they improved their decision-making skills by learning from their mistakes, decided how to place the blocks (11%), developed their problem-solving skills on robotic coding (8%), and learned from each other's ideas (8%), and they thought about how robotic coding was implemented (8%) thanks to the robotic coding activities. Therefore, they used the decision-making process. One of the students stated that the robotic coding training made him feel confident and that he made a better decision in this way. Two students (8%) stated that the robotic coding activities did not have any impact on their decision-making skills. One of these students (4%) stated that he had problems in decision-making because he could not get along with his group mates.

S5: "It helped my decision-making skills because it made me feel confident about what I was doing." S6: "It helped me decide how to place the Lego blocks."

Table 9

Students' Views on the Third Question

Category	Code	Frequency (F)	Percentage (%)
Shared person	Teacher	7	47
	Friend	6	40
No	Inability to share easily	2	13
Total		15	100
Reason to share	A better understanding	5	38
	Reaching a solution	3	23
	Help-seeking	3	23
	Being willing to share	1	8
	Enjoyableness	1	8
Total		13	100

Table 9 shows the answers to the question "Did you share your ideas with your friends and teachers during the activities; why did you share them?" along with the codes and categories. Most of the students (87%) were able to share their ideas with their teachers or friends. Out of the surveyed students, only 2 did not share their ideas easily and stated that they were embarrassed to do so. The reasons for sharing the ideas of the students consisted of gaining a better understanding of the activities, reaching a solution, asking for help, being willing to share, and enjoyableness of sharing ideas. The most common reason for sharing ideas (38%) was for a better understanding of the activities. The students preferred to share their ideas to perform the coding better. Furthermore, 23% of the students shared their ideas with friends and teachers to assist in finding a solution. The students who shared their ideas because they thought it was fun and they were willing to do so accounted for 8% of the participants.

S9: "I couldn't share my ideas easily; I was embarrassed." S10: "I was comfortable sharing my ideas because it was necessary for me to get help."

Discussion and Conclusion

The present study was conducted to determine the effect of STEM-based robotic coding education on the decision-making skills of primary school students. Based on the quantitative results, there was an improvement in their decision-making skills after the implementation process. The findings obtained from the interview also revealed that the students' decision-making skills improved as a result of the robotic coding training given for 6 weeks. In other words, STEM-based robotic coding education positively affected primary school students' decision-making skills. The results of the experiment show that there was a significant improvement in the final test scores of the experimental group, while no significant difference was observed in the control group. This suggests that the application had a positive impact on the experimental group. Although there was no significant difference between the pretest and posttest scores in the control group, there was a decrease in the posttest scores. A similar decrease was also observed in a previous study by Bozanoğlu (2005) in the field of educational sciences. It is possible that external factors may have affected the decision-making process of the control group, leading to this decrease. In fact, Realyvásquez-Vargas et al. (2020) stated that adverse environmental factors can negatively influence final test scores. Furthermore, the diversity among educators in the control group and the varying pedagogical approaches and strategies they use in teaching the subject are considered possible factors in this scenario. The findings reported by Vanlommel et al. (2018) suggest that teachers' instructional approaches and attitudes have a noteworthy impact on the decision-making skills of students. That study's results can be identified as a potential explanation for the changes observed in the control group.

Karahan et al. (2023) claim that creative thinking skills predict primary school students' decision-making skills since decision-making is one of the dimensions of creative thinking abilities. Accordingly, it can be inferred that activities that can improve creative thinking skills can also affect decision-making skills. In fact, it has been suggested in numerous studies that robotic coding education positively impacts students' creative thinking skills (Zhang and Zhu, 2022; Arslan and Çelik, 2022) and this has been demonstrated in experimental studies (Tiryaki and Adıgüzel, 2021; Noh and Lee, 2020). The present study also supports similar studies in terms of showing how robotic coding training develops decision-making skills, one of the skills that make up creative thinking.

According to the analysis of the pre- and posttest means for the subdimensions of the decision-making skills scale, no significant differences were detected in the subdimensions of realizing and identifying the problem, gathering information, generating alternative options, or implementing and evaluating the decision in the control group. The control group, however, demonstrated a significant difference favoring the pretest in the subdimension of decision-making. A significant difference was found in favor of the posttest in the subdimensions of decision-making and implementation and evaluation in the experimental group. The significant difference can be attributed to the robotic coding activities. In addition, the experimental group's posttest means were significantly higher than the pretest means in the subdimensions of realizing and identifying the problem and generating alternative options. Based on the qualitative results, the students stated that they developed their decision-making skills as a result of the activities. They could make better decisions and support their decision-making by thinking about how to perform robotic coding activities, attempting to solve the problems they faced, and making sure of their coding.

Considering the qualitative findings, it is clear that the students encountered some problems while performing the robotic coding activities. These problems were generally caused by the incorrect layout of the blocks, incorrect coding, and disagreements with group mates. These problems are likely due to the young age of the group receiving the robotic coding training and the fact they had never participated in such activities before. In addition, since the students carried out these activities in groups, it was inevitable that sometimes communication problems could occur within groups. The qualitative findings also confirm a significant increase in terms of the experimental group's subdimension of realizing and identifying the problem. The students were able to identify the problems they had during the robotic coding activities and found solutions to them. Moreover, according to the qualitative findings, the students tried various alternatives besides getting help from their friends and teachers to solve the problems they encountered. For instance, when they could not place the blocks, they changed the items or when their coding was wrong, they were able to correct it by creating different codes. Therefore, the considerable increase in the experimental group's subdimension of generating alternative options supports these findings. Moreover, in the study conducted by Çakır and Altun Yalçın (2021), the students stated that they tried different alternatives to solve their problems and received help from teachers and friends. These findings also overlap with the qualitative results of the present study. Therefore, it appears that students' ability to create alternatives and develop solution options to problems increased due to the robotic coding activities. It is thought that this situation also strengthens the students' decision-making skills, because during the decision-making process, first of all, the problem is defined, then the alternatives for the solution of this problem are determined, and the most appropriate option to obtain the solution is decided on (Adair, 2000).

According to Yurtseven et al. (2021), a correlation exists between primary school students' problem-solving skills and their decision-making, and it was concluded that decision-making was positively correlated with problem-solving skills, and problem-solving skills were predicted by decision-making. Therefore, a key finding of this research is that decision-making and problem-solving skills are closely related and that they affect each other positively. Moreover, there are many studies indicating that robotic coding education improves students' problem-solving skills (Atmatzidou et al., 2018; Çalışkan, 2020), and the results of the relevant studies support the findings of the present study. Consequently, within the framework of our research and similar research results, it can be inferred that there is an interrelationship between skills regarding problem-solving, computational thinking, creativity, critical thinking, and decision-making, and, therefore, an increase in any of these skills might positively affect other skills. However, the experimental and control group did not differ significantly in the subdimension of gathering information. Nevertheless, considering the qualitative data, although the students did not make clear statements about the information-gathering process, getting help from their teachers and friends and completing the activities by asking them questions show to some degree that they collected some information. However, due to the practice-oriented nature of robotic coding and low education levels of the students in terms of conducting theoretical research or gathering information, it is estimated that information-gathering could not be adequately performed. Another finding obtained from the qualitative data is that the majority of the students were willing to share their ideas and solutions. As a result of this process, the students saw that they could create models and solve problems on their own, and they were enthusiastic and excited to share their ideas. Cakir and Altun-Yalcin (2022) examined students' views on STEM education and concluded that they showed an improved sense of curiosity and self-confidence. In this respect, it can be concluded that robotic coding activities help students improve not only in terms of cognitive skills but also in other areas such as socialization, communication, self-confidence, and motivation. Other studies in this field also support this result. Kandlhofer and Steinbauer (2016) reported that educational robotics applications improved students' social skills. Furthermore, Yang et al. (2000) concluded that students found educational robotics fun, resulting in increased motivation, and Vourletsis and Politis (2000) concluded that the ability to solve problems through robotic coding improved students' self-confidence as well.

Recommendations

The present study had the following limitations: the application period was limited to 6 weeks, it only involved 3rd-grade primary school students, and no other robotic tools were used in training process apart from the Fischertechnik set and ROBO pro software. Therefore, a longer-term robotic coding training program can be conducted with students at various levels in this field. Studies can be implemented with different robotic tools. In addition, it is thought that more experimental studies involving students' affective skills will make a significant contribution. As a final note, it is crucial to emphasize individuals' decision-making and problem-solving abilities from the beginning of the elementary level. Thus, beginner-level coding courses or activities aimed at developing these skills should be integrated into primary school programs.

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Statement of Responsibility

Multi-author publications have taken the necessary responsibility including the tasks such as conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing-original draft, writing-review&editing, visualization, supervision.

Meryem Meral-Language, Literature review, Data analysis, Conclusion

Sema Altun Yalçın-Data collection, Results, Conclusion

Zehra Çakır-Methodology, Data curation, validity

Esila Samur- Methodology, Data curation, Validity

Conflicts of Interest

There is not any conflict of interest that could influence our research.

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