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# The Impact of Robotic Coding Applications on Elementary School Students' Metacognitive Skills and Attitude Towards Robotic Coding

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## SUMMARY

The purpose of this study is to investigate the impact of robotic coding activities on elementary school students' metacognitive skills and attitudes towards robotic coding. A mixed-method approach was employed in the research, utilizing a single group pre-and post-test design. The study sample consisted of 20 students enrolled in the fourth grade of primary school. Students were administered pre-tests which measured their metacognitive skills and attitudes towards robotic coding. Subsequently, the students received robotic coding training for a duration of six weeks. Following the implementation, the same scales were administered as post-tests to the same group. Quantitative data were analyzed using the paired samples t-test. The post-test revealed a statistically significant increase in students' metacognitive skills and attitudes towards robotic coding, including all sub-dimensions of the scales. Semi-structured interviews were conducted with 20 students, comprising four questions to collect qualitative data. The interview outcomes were subjected to the content analysis. The qualitative findings demonstrated the beneficial effects of robotic coding training on students' attitudes, including enhanced motivation, collaboration, and self-confidence. Based on the study results, actionable recommendations have been proposed.

**Keywords:** Attitude towards robotics coding, metacognitive skills, elementary school students

## INTRODUCTION

Technology is integrated into education through various tools and platforms (Georgina and Olson, 2008), and robotic applications are one of these tools. The use of robotic applications in education, including the utilization of robotic sensors, motors, and similar components, has gained prominence in recent years (Rogers et al., 2010). Educational robotics, as a field, supports the learning and teaching processes through the incorporation of robotics (Mikropoulos and Bellou, 2013). Within this framework, the usage of various educational robots, robotic kits, and robotic coding platforms has become popular in the field of education, encouraging the widespread adoption of robotic applications in classrooms (Monteiro, Ramirez ve Enríquez., 2019).

Educational robotics is being actively integrated into teaching in schools and courses through various activities, as stated by Seckin-Kapucu (2023). In this context, in-service training sessions are organized for teachers to enhance their knowledge and skills in educational robotics (Filipov et al., 2017). There are diverse initiatives such as robot competitions, projects, and workshop training programs for students (Chung et al., 2017). These activities aim to develop awareness among educators and students of the key elements of education, focusing on STEM (Science, Technology, Engineering, and Mathematics), robotics, and digitalization. Various essential outcomes of educational robotics have been enhanced through the implementation of these activities. The outcomes of incorporating robotics in education include the development of students' problem-solving skills (Altun-Yalçın et al., 2020; Zhang and Zhu, 2022), fostering creative and innovative thinking (Aris and Orcos, 2019; Adams et al., 2010), strengthening teamwork and collaboration skills (Eguchy, 2017), supporting individuals' self-confidence and motivation (Skelton et al., 2011; Castledine and Chalmers, 2011; Aris and Orcos, 2019), and instilling positive attitudes and awareness towards engineering and technology (Anwar et al., 2019).

According to a study conducted by Goel and Gupta (2020), emphasizing these objectives and focusing more on 21st-century skills will facilitate individuals' preparation for the innovative world of the future. By taking advantage of this opportunity, individuals will greatly enhance their qualifications and become more competitive in their respective industries. Numerous studies on educational robotics applications consistently demonstrate their support for students in various areas, with cognitive and affective skills at the forefront. Papadakis and

Kalogiannakis (2022) investigated the impact of the BeeBot educational robotics applications on the computational skills of preschool students. The research concluded a significant increase in computational thinking scores in favor of the final test. Besides computational thinking, cognitive skills such as problem-solving, creativity, critical thinking, and algorithmic thinking have also been frequently studied. Badeleh (2021) found that robotic education provided to high school students positively influenced their creativity. Zhang and Zhu (2022) observed that educational robotics applications enhanced students' problem-solving skills. Moreover, studies conducted in the related field have explored the effects of educational robotics on variables such as algorithmic and logical thinking (Evripidou et al., 2021; Castelblanco et al., 2019), motivation (Aris and Orcos, 2019; Cejka, 2006), self-confidence (Piedade et al., 2020), experience (Theodoropoulos et al., 2017), perspective (García-Carrillo et al., 2021), and collaboration (Agrusti and Bonavolontà, 2022). Educational robotics significantly impacts these variables, as demonstrated in these investigations.

**Problem state**

The majority of studies in the field of educational robotics primarily focus on cognitive skills such as problem-solving, creativity, and information processing thinking. While the development of these cognitive skills is crucial, there is a growing recognition of the need to emphasize the cultivation of certain other cognitive abilities that are highly significant for individuals. Metacognitive skills are one such set of cognitive skills. Metacognitive skills can be defined as the abilities of an individual to monitor, plan, organize, and become aware of how they learn and think (Pintrich, 2002; Swanson, 1990). Similarly, Flavell (1976) characterizes metacognition as "awareness directed at one's cognitive processes or knowledge capacity in any given field." Wellman (1985) further delineates this term as "thinking about one's own thinking."

In accordance with these definitions, it can be asserted that metacognitive skills are highly crucial for individuals in terms of organizing and planning their own learning and thinking processes. Moreover, relevant studies emphasize the significant role of metacognitive thinking in individuals' problem-solving in their lives and the perspectives they adopt towards these problems (Berardi-Coletta et al., 1995; Sandi-Urena et al., 2012; Zhao et al., 2019). According to Shekhar and Rahnev (2021), metacognitive thinking skills directly influence an individual's decision-making abilities. Tzohar-Rozen and Kramarski (2017) posit that metacognitive thinking skills are a factor affecting students'academic learning and achievements. Efklides (2006) highlights three areas where metacognition plays a role: knowledge, including beliefs, strategies, and cognitive functions; experience, involving factors like confidence, frustration, and effort estimation; and skills, such as planning, control, and evaluation of cognitive processes. These aspects enable individuals to gain insights, improve their abilities, and achieve greater success in life.

Furthermore, a concept believed to be associated with metacognition is attitude (Dewi and Muzammil, 2020). Activating metacognitive skills can shape an individual's thinking process and, in turn, alter their attitudes towards events and problems (Memiş and Kandemir, 2019). Attitude can be defined as the emotional, cognitive, belief, or behavioral disposition towards an object or subject (Hsu and Huang, 2018). Therefore, it is crucial for students to have a positive attitude towards robotics for their success in and future involvement with this field. Individuals with a negative attitude towards robotics are less likely to be interested in and develop themselves in this area. In this regard, introducing students to robotics from an early age is important. Furthermore, numerous studies suggest that robotic education should be offered at the elementary level (Sullivan and Bers, 2016; Elkin et al., 2014; Zviel-Girshin et al., 2020). Similarly, it has been suggested that providing metacognitive skills from an early age would be more effective (Chatzipanteli et al., 2014). In this regard, several pedagogical strategies and instructional methods have been applied. Leading approaches include problem-based learning, project-based learning, the use of mind maps, cognitive apprenticeship, self-regulatory techniques, and cooperative learning models such as 5E and 7E (Arslan & Gelişli, 2017; Downing et al., 2009; Wismath & Orr, 2015; Lucitasari et al., 2021). In addition to these approaches and methods, educational robotics, which has emerged as a significant field in recent years, is also employed to foster individuals' metacognitive abilities.

Atmatzidou et al. (2018) investigated the impact of educational robotics on high school students' metacognitive skills and found that robotic education had a positive effect on metacognitive skills. Socratous and Ioannou (2019) conducted a similar study, investigating the impact of educational robotics applications on elementary school students' metacognitive skills and obtained similar positive results. However, Özkan and Toz (2022) pointed out that there is a relatively limited number of studies examining the effects of educational robots on metacognitive skills, suggesting that researchers in the field should further investigate the impacts of educational robotics on metacognitive skills. Furthermore, studies focusing on the impact of robotics on metacognitive skills in elementary school students are scarce, and based on the relevant literature, these studies have predominantly employed quantitative methods. In this study, it is believed that combining both quantitative and qualitative methods will yield richer data.

Additionally, systematic reviews in the field of educational robotics reveal that in many studies; Lego Mindstorms, Arduino, BeeBot, Python, and Scratch platforms are commonly used (Çetin and Demircan, 2020; Souza et al., 2018). Although these platforms and sets are commonly favored, it is recognized that various sets and software options exist. However, their inclusion in research is limited, highlighting a gap in the current literature. Therefore, in this study, it is considered that the preference for the Fischer Technic set and RoboPro software, which are less represented in research, will contribute to the field. This educational robotics tool distinguishes itself from many others through its streamlined and user-friendly interface, facilitating an accessible and efficient learning experience for students. In light of these considerations, this study aims to investigate the impact of educational robotics applications on elementary school students' metacognitive thinking and attitudes. In this context, the following research questions are addressed:

1. Do educational robotics applications have an impact on the metacognitive thinking of elementary school students?
2. Do educational robotics applications influence the attitudes of elementary school students towards robotic coding?
3. What are the views of elementary school students regarding educational robotics applications?

## METHOD

### Research design

The research employs an explanatory sequential mixed-methods design. The preference for an explanatory sequential design arises from its nature as a mixed-methods pattern where quantitative data take precedence, followed by the collection of qualitative data to enhance the explanation of quantitative findings (Tashakkori and Creswell, 2007; Bowen et al., 2017). The choice of the explanatory sequential design in this study aims to delve deeper into the research questions and enrich the data, thereby enhancing the reliability of the study (Creswell et al., 2003; Ivankova et al., 2006). In the quantitative phase of the research, the experimental design of a single-group pretest-posttest model is employed. The single-group pretest-posttest model involves the application of an independent variable to a single group, with measurements taken both before and after the application of the independent variable (Marsden and Torgerson, 2012). In this model, the effect of the independent variable is assessed by examining the difference between the pre-test and post-test (Meyer et al., 2019). For the qualitative phase of the research, semi-structured interviews consisting of open-ended questions prepared by the researchers were conducted. Through these interviews, researchers had the opportunity to obtain data containing participants'expressions regarding the perceived situations or events (Patton, 2014).

### Study sample

The universe of the research consists of elementary school students, and the sample comprises 20 4th-graders. Due to the significant time required for each student to code independently and the intricate and time-consuming process of constructing LEGO models, the number of participants in the study was necessarily limited. Additionally, a larger participant group would hinder the instructor's ability to observe each student individually. For these reasons, only 20 students were included in the study. In the research, a non-probability sampling method, specifically the convenience sampling method, has been chosen. Convenience sampling is preferred due to practical criteria such as geographical proximity and ease of access (Etikan et al., 2016).

Table 1. The Demographic Characteristics of the Study Sample

| | | N | Grade |
|---|---|---|---|
| Experimental group | Pre-test | 20 | 4thgrade |
| | Post-test | 20 | 4th grade |

### Implementation

The "Metacognitive Skills Scale" and the "Robotic Coding Attitude Scale" were administered to the group before the implementation. Initially, the students were divided into groups of 3 and 4 individuals. Each group was provided with "Fischer Technik" building blocks. Additionally, each group had expert instructors in their respective fields. The students first created prototypes of engineering designs using the building blocks. These prototypes include a traffic light, a carrousel, a washing machine, as well as automatable doors and barrier gates used for entry and exit control in various locations. Subsequently, the students coded and executed the functions of these structures. Expert instructors only observed the students and provided each student with different problem states for coding, checking whether or not they correctly coded. Finally, all students in the group were given a higher-level code that they could collectively think about, discuss, and code together. In this way, each student had the opportunity to engage in coding individually, and they also had the opportunity to work collaboratively to find solutions to problems they encountered.

The stages of the implementation process of the research are presented in Figure 1.

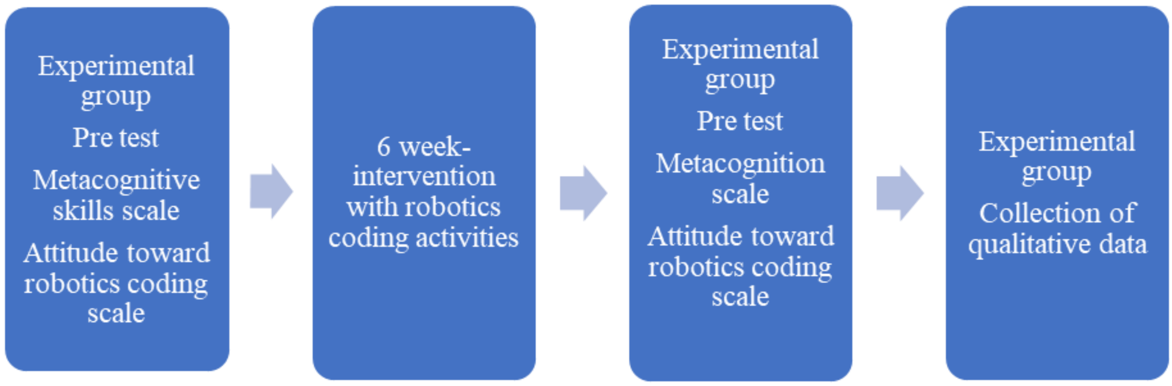


*Figure 1.* The application process of the research

**Data collection tools**

The "Metacognitive Skills Scale," developed by Çetinkaya (2000), consisting of 32 questions, was administered to measure students' higher-order cognitive thinking skills. This scale comprises four sub-dimensions: self-control, awareness, cognitive strategy, and evaluation. The reliability of this scale, assessed using Cronbach's alpha, was found to be 0.82 for the 4-point Likert-type form. The "Robotic Coding Attitude Scale" developed by Altun-Yalçın et al. (2020) was utilized to measure students' attitudes toward robotic coding. This scale, consisting of five sub-dimensions (interest, motivation, learning desire, self-efficacy, anxiety), demonstrated a Cronbach's alpha value of 0.91. The scale is in a 5-point Likert format. Semi-structured interviews were conducted with 20 students after the application process to collect qualitative data. The interview comprised four questions aimed at eliciting the students' feelings and thoughts about the activity.

**Data analysis**

The quantitative data were initially tested for normal distribution using the Shapiro-Wilk test. Data sets with a normal distribution were analyzed using the t-test for paired samples to analyze mean differences and significance values. The scales were analyzed separately for overall scores and sub-dimensions. The content analysis technique was utilized for the analysis of the qualitative data. Content analysis is an analytical method aiming to summarize a phenomenon (or occurrence) and obtain a comprehensive definition of it. It involves the creation of concepts or categories that explain the phenomenon after the analysis. Content analysis allows the researcher to analyze the data intuitively, sensitively, and interpretatively (Hsieh and Shannon, 2005).

**Validity and reliability**

The validity of the quantitative part of the study was ensured by providing students with careful instructions to fill out the scale. To mitigate the risk of subject loss and maturation impact, the application duration was kept short. Additionally, reliability analysis, specifically Cronbach's alpha, was conducted for the scales. The Cronbach Alpha values obtained in this study were 0.943 for the pre-test and 0.848 for the post-test of the Robotic Coding Attitude Scale and the Cronbach alpha values were 0.911 for the pre-test and 0.857 for the post-test in the Metacognitive Skills Scale. A Cronbach alpha value greater than 0.70 indicates that the scale is reliable (Taber, 2018).

In terms of the validity of the qualitative dimension of the research, students must provide honest answers (Rose and Johnson, 2020). At the outset of the study, the students were given reassurance to alleviate any concerns they might have had, and communication was established with them to ensure a smooth and successful experience. During the process of coding qualitative data, codes and categories were verified through direct quotes by both experts and participants. The reliability of qualitative data was calculated using the formula suggested by Miles and Huberman (2014) (Reliability = Agreement / Agreement + Disagreement). The agreement rate between codes and categories, independently created by two different researchers in the field, was determined according to this formula. Based on this formula, the reliability coefficient was calculated as 91%.

## FINDINGS

### Findings on quantitative data

The data obtained from the scales were subjected to a normality test. The Shapiro-Wilk results are presented in Table 2.

Table 2. Normality Test Results of Quantitative Data

| Scale | | N | Shapiro-Wilk |
|---|---|---|---|
| Metacognitive skills | Pre-test | 20 | ,344 |
| | Post-test | 20 | ,274 |
| Robotic coding attitude | Pre-test | 20 | ,248 |
| | Post-test | 20 | ,915 |

Given the participant size falling below 50 (Razali and Wah, 2011), a Shapiro-Wilk test was executed to examine the normality assumption. If the result of the Shapiro-Wilk test is greater than 0.05, the data set is assumed to be normally distributed (Razali and Wah, 2011). Therefore, since the values for both pre and post-test for both scales were greater than 0.05, it is assumed that the data set is normally distributed. Parametric tests are conventionally applied when the data set follows a normal distribution. Although the sample size in this study is below 30, several studies have indicated that the t-test remains more reliable and grounded in stronger theoretical assumptions compared to non-parametric alternatives, even with small samples (De Winter, 2013; Wilcox, 2011). Therefore, the use of the t-test was considered appropriate for this study.

Table 3. Paired Sample t-Test Results for the Scales

| Scale | | N | x̄ | Sd | t | p |
|---|---|---|---|---|---|---|
| Metacognitive skills | Pre-test | 20 | 84,550 | 15,188 | | |
| | | | | | -6,929 | ,000 |
| | Post-test | 20 | 110,750 | 9,618 | | |
| Robotic coding attitude | Pre-test | 20 | 76,700 | 18,379 | | |
| | | | | | -7,348 | ,001 |
| | Post-test | 20 | 93,700 | 9,641 | | |

Table 3 presents the results of the paired sample t-test for the scores of the scales. Arithmetic means were derived from the total scores of the scales. The arithmetic mean of the final test for the Metacognitive Skills scale ($\bar{x}$=110.750) is higher than the pre-test mean ($\bar{x}$=84.550). Similarly, the final test mean for the Robotic Coding Attitude scale ($\bar{x}$=93.700) is higher than the pre-test mean ($\bar{x}$=76.700). For both scales (Metacognitive Skills, Robotic Coding Attitude), the p-value is less than 0.05, indicating a significant increase in favor of the final test for both scales.

Table 4. Paired Sample t-Test Results for Sub-dimensions of the Metacognitive Skills Scale

| Sub-dimension | Measurements | N | x̄ | Sd | t | p |
|---|---|---|---|---|---|---|
| Self-control | Pre-test | 20 | 22,600 | 5,403 | -4,406 | ,000 |
| | Post-test | 20 | 27,800 | 2,820 | | |
| Awareness | Pre-test | 20 | 19,800 | 5,267 | -5,983 | ,000 |
| | Post-test | 20 | 27,750 | 2,788 | | |
| Cognitive strategy | Pre-test | 20 | 21,850 | 4,545 | -8,182 | ,000 |
| | Post-test | 20 | 30,900 | 3,041 | | |
| Evaluation | Pre-test | 20 | 23,000 | 5,321 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | -6,927 | ,000 |
| | Post-test | 20 | 31,400 | 3,362 | | |

Table 4 shows a significant difference in favor of the final test for all four sub-dimensions of the Metacognitive Skills scale (p<0.05). These sub-dimensions include self-control, awareness, cognitive strategy, and evaluation.

Table 5. Paired Sample t-Test Results for Sub-dimensions of the Robotic Coding Attitude Scale

| Sub-dimension | Measurements | N | x̄ | Sd | t | p |
|---|---|---|---|---|---|---|
| İnterest | Pre-test | 20 | 14,800 | 4,323 | -3,155 | ,005 |
| | Post-test | 20 | 18,150 | 2,084 | | |
| Motivation | Pre-test | 20 | 13,750 | 3,971 | -13,124 | ,000 |
| | Post-test | 20 | 28,600 | 4,284 | | |
| Desire for learning | Pre-test | 20 | 13,350 | 3,150 | -4,613 | ,000 |
| | Post-test | 20 | 17,400 | 2,137 | | |
| Self-efficacy | Pre-test | 20 | 13,450 | 3,859 | -3,736 | ,001 |
| | Post-test | 20 | 16,850 | 1,785 | | |
| Anxiety | Pre-test | 20 | 3,700 | 1,525 | -5,734 | ,000 |
| | Post-test | 20 | 7,600 | 2,233 | | |

Upon reviewing Table 5, it is apparent that there is a statistically significant difference in favor of the final test for all five sub-dimensions of the Robotic Coding Attitude scale (p<0.05). These sub-dimensions encompass interest, desire for learning, self-efficacy, and anxiety.

**Findings on qualitative data**

The findings of qualitative data were analyzed through content analysis, and the results are presented in Tables 6, 7, 8, and 9 with frequency and percentage values.

Table 6. The Views of the Students Regarding the First Question

| Category | Code | Frequency (F) |
|---|---|---|
| Positive | Entertaining | 10 |
| | Learning new things | 8 |
| | Liking | 7 |
| | Working in a group | 4 |
| | Solving problems together | 2 |
| | Innovation | 2 |
| | Desire to repeat | 2 |
| | Self-discovery | 2 |
| Negative | Absence of negativity | 12 |
| | The difficulty of coding | 2 |
| | Multiplicity of tasks | 1 |
| Total | | 52 |

In Table 6, responses to the question “What do you think about these activities? What are the positive and negative aspects?” are categorized into positive and negative. The code with the highest frequency (f=10) in the positive category is “fun.” The majority of students found the activities enjoyable. Following this, the codes “learning new things” (f=8) and “liking” (f=7) also have high frequencies. Students perceive robotics and coding as new activities for them. They mentioned enjoying the activities, learning new things, and expressing a desire to participate in similar activities again (f=2). Additionally, some students highlighted the opportunity to work with group mates (f=4) and solve problems collaboratively as a team (f=2). A few students (f=2) mentioned that through robotics coding activities, they explored their strengths and weaknesses, gaining self-awareness. Furthermore, a significant number of students (f=12) believes that these activities have no negative aspects. Only two students mentioned struggling with coding, and one student expressed that there were many and intense tasks during the activities.

*S1: “The activities were very entertaining; I would like to do them again.”*

*S2: “These activities were something entirely new for me. Through them, I learned things related to robotics and coding.”*

*S3: "There were too many tasks, and at times, I found it challenging to complete them."*

Table 7. The Views of the Students Regarding the Second Question

| Category | Code | Frequency (F) |
|---|---|---|
| Learning | Coding | 7 |
| | Attaching legos | 4 |
| | Team work | 3 |
| | Innovation | 3 |
| | The functioning mechanism of tools | 2 |
| Interest | Interest in the field | 3 |
| | Interest in relevant careers | 1 |
| Other | Entertainment | 6 |
| | Self-recognition | 2 |
| Total | | 31 |

The responses to the question "Did these activities contribute to you? Why?" are categorized into three categories: learning, interest, and other. The code with the highest frequency (f=7) in the category "learning" is "coding". The majority of students mentioned that they learned robotic coding through these activities. This code is followed by the codes "entertainment" (f=6) and "attaching legos" (f=4). Students emphasized that they had a highly enjoyable experience through robotics and coding. They also mentioned learning to connect legos and other parts, improving their skills in assembling more complex and challenging pieces compared to their previous experiences with legos. Additionally, students mentioned learning new features of robots (f=3), understanding how appliances like washing machines and merry-go-rounds work (f=2). Some students stated that they developed teamwork skills (f=3) and got to know themselves better in terms of coding and assembling legos (f=2). A few students (f=3) expressed that through robotics coding activities, they developed an interest in robotics and engineering fields, while one student mentioned aspiring to have a career in this field in the future.

*S1: "Thanks to the activities, I learned how to code on the computer."*

*S2: "Learning to attach legos through the activities was quite enjoyable for me."*

Table 8. The Views of the Students Regarding the Third Question

| Category | Code | Frequency (F) |
|---|---|---|
| Benefit | Entertainment | 9 |
| | Learning | 6 |
| | Spending time | 3 |
| Interest | Interest in legos | 5 |
| | Interest in robotics | 4 |
| | Interest in coding | 2 |
| Total | | 29 |

In Table 8, responses to the question "Would you like to do activities like these again? Why?" are categorized into the categories called "benefit" and "interest". "Entertainment" has the highest frequency (f=9) in the category called "benefit". The majority of students mentioned that they had fun through the activities. Additionally, "learning" (f=6) is among the mentioned benefits. The students expressed that the activities taught them how to attach new legos, to code, and to work in teams, and this contributed significantly to their development. Therefore, they expressed a desire to do more of these activities. Some students (f=3) mentioned that they had the opportunity to spend quality time with their group mates. In the category called "interest", the code with the highest frequency is "interest in legos" (f=5). Some students (f=5) mentioned that they already had an interest in legos, and others expressed an interest in robotics (f=4) and coding (f=2), stating that they wanted to do these activities again because of their existing interest.

*S1: "I have an interest in playing with legos. Therefore, I would like to engage in activities like these again."*

*S2: "I would like to participate in robotics coding activities again because I thoroughly enjoy both having fun and learning during these sessions."*

Table 9. The Views of the Students Regarding the Fourth Question

| Category | Code | Frequency (F) |
|---|---|---|
| Yes | Collaboration | 9 |
| | Cooperation | 7 |
| | Self-confidence | 1 |
| No | Disaggreement | 3 |
| Total | | 20 |

In Table 9, responses to the question "Did these activities contribute to your communication with friends? Why?" are categorized into yes and no. The majority of students asserted that the activities strengthened collaboration (f=9) and cooperation (f=7) with their friends. They mentioned seeking help from friends to solve certain problems and collaborating with friends to place legos and engage in coding together. However, some students (f=3) mentioned experiencing disagreements and moments of miscommunication regarding coding and assembling legos. One student mentioned feeling more comfortable communicating with group mates during the activities, and gaining self-confidence in communication compared to feeling embarrassed to ask for help from friends before the activities.

*S1: "I used to struggle with communicating with my friends, and I felt embarrassed when asking for help. However, through the activities, I learned to communicate more comfortably with my friends."*

*S2: "When we couldn't solve the problem, we were able to get help from our friends. By collaborating, we managed to code and build legos together."*

## CONCLUSION AND DISCUSSION

This research investigates the influence of educational robotics applications using the Fischer Technic robotics kit on elementary school students'metacognitive skills and attitudes. Quantitative data obtained from the study indicate a significant increase in students'metacognitive skills and attitudes across all sub-dimensions in favor of the post-test. Findings from interviews reveal that the six-week robotics coding training positively influenced students'attitudes towards robotics, demonstrating that they found the robotics experience beneficial. In other words, educational robotics applications have positively enhanced students'metacognitive skills and attitudes.

Socratous and Ioannou (2019) demonstrated that educational robotics enhances students'metacognitive regulation. The findings of this study further support the relevant literature by revealing statistically significant increases in all sub-dimensions of metacognitive skills (self-control, awareness, cognitive strategy, and evaluation). Additionally, qualitative findings indicate that students can solve problems more easily, discover their strengths and weaknesses, and gain more self-confidence through educational robotics applications. It is a highly predictable result that students who develop self-confidence and succeed in solving problems also enhance their metacognitive skills, since self-confidence and successful problem-solving strategies can directly influence metacognition (Güner and Erbay, 2021). Quantitative and qualitative findings are compatible in this context, thus supporting each other. Reviewing the relevant literature, it is evident that educational robotics applications enhance students'self-confidence and self-efficacy in problem-solving (Skelton et al., 2011; Castledine and Chalmers, 2011; Tsai et al., 2021). Additionally, students acquire self-awareness (Nilson and Zimmerman, 2013) and self-evaluation skills (Gratani et al., 2021). Furthermore, according to studies, educational robotics has been proven to enhance the development of metacognitive skills, as supported by the findings of this research. These findings serve as a testament to the effectiveness of educational robotics in promoting the acquisition of skills associated with the sub-dimensions of metacognition.

The research indicates that educational robotics applications have significantly enhanced the attitudes of elementary school students towards robotic coding. There is a significant increase in each sub-dimension of attitudes towards robotic coding, including interest, motivation, desire for learning, self-efficacy, and anxiety. Students engaged in interactive and hands-on training through educational robotics applications. As a result, they gained practical experience by implementing theoretical knowledge on their own. This hands-on experience positively influenced their interest in educational robotics. Positive changes in attitudes have been brought about by an increase in interest in this area.

Furthermore, as students gained confidence in solving their own problems, they became more motivated. Consequently, they expressed a greater desire to receive more education on robotic coding. Through these activities, students gained a better understanding of their strengths and weaknesses, leading to the development of self-efficacy skills. The increased motivation for learning and the enhancement of self-efficacy have been crucial factors contributing to the significant improvement in attitudes towards robotic coding. It is due to the presence of self-efficacy and a desire for learning as subdimensions of the attitude. Qualitative findings, which encompass these variables, support the quantitative findings related to the attitude. According to qualitative data, most students found robotic coding activities enjoyable. Many students expressed a strong liking for these activities, stating that there were no negative aspects to them. As a result, students reported an increased interest in robotic coding and engineering fields, expressing a desire to repeat the activities and learn more in this area. In this context, it has been observed that students'attitudes towards robotic coding are positive and further enhanced as a result of these activities. Numerous studies in the relevant field have also shown that educational robotics applications increase students'attitudes (Kandlhofer and Steinbauer, 2016; Cejka et al., 2006; Welch and Huffman, 2011; Sisman et al., 2021).

The qualitative and quantitative findings indicate the development of students'motivation through robotic coding activities. Students expressed a higher level of motivation in dealing with legos and learning to code. Collaborating in groups, spending time together, helping each other solve problems, and successfully mastering coding have been effective in this behavioral development. The development of interest and motivation guides an individual's behavior, thereby influencing their attitude (Potvin and Hasni, 2014). Based on this statement, it can be asserted that the increase in interest, motivation, self-efficacy, and desire for learning are underlying factors that contribute to the increase in attitude. Studies supporting the idea that educational robotics enhances students'interest and motivation also align with the findings of this research. Chin et al. (2014) proposed that educational robots improve students'interest, satisfaction, and motivation. Besides, Anwar et al. (2019) conducted a systematic analysis based on the findings of studies in the field of educational robotics. The study demonstrated that educational robotics positively influenced students'interest, motivation, and overall attitudes. As students'motivation increased, they became more willing to learn, leading to an increase in their desire to learn and a decrease in anxiety levels.

Considering both qualitative and quantitative findings, it is evident that students have less prejudice regarding coding and robotics after completing robotic coding training. This positive change in attitude contributes to a reduction in their anxiety levels. As students express, enjoyment of the robotic coding process and having fun with their peers has also contributed to the decrease in anxiety levels. Indeed, Yılmaz-Ince and Koç (2020) stated in their study that students found robotic coding enjoyable, had a fun and learning opportunity, experienced a more effective learning environment through robotic coding activities, and developed self-confidence. In summary, the results of this study indicate that robotic coding activities not only enhance students'metacognitive skills and attitudes but also improve related factors such as self-efficacy, self-confidence, problem-solving abilities, collaboration, interest, and motivation. These results are consistent with similar research conducted in the field of educational robotics.

**Recommendations**

Students can be offered a more efficient and enjoyable learning environment through robotic coding. Hence, it is advisable to advocate for the extensive integration of these activities and facilitate the arrangement of workshops and courses for educators and students in this domain. Researchers should thoroughly examine the relationship between attitudes and robotic coding at different levels. Additionally, it is recommended to explore the connection between various cognitive skills and robotics. Furthermore, it is suggested to execute the study with the inclusion of a controlled experimental group and a larger participant cohort.

**Limitations**

This study lacks a control group, presenting a potential challenge to the internal validity of the research. Furthermore, the Fischer Technic robotic set employed in this study is characterized by a high cost, potentially restricting its accessibility across diverse socioeconomic levels. Another constraint of the study lies in the notably modest sample size, thereby diminishing the external validity or so-called generalizability of the study.

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