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Does really educational robotics improve secondary school students' course motivation, achievement and attitude?

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Abstract

This study examines the impact of educational robotics applications in Information Technologies and Software courses on the motivation, attitude towards robotics, and academic achievement of 6th-grade secondary school students. The research employed pre-experimental method encompassing 112 students. Students got training in robotics using the Arduino education kit over the course of eight weeks consisted of programming and electronic concepts. Findings indicate that while students' motivation levels were moderate both before and after the implementation, there was a relative decrease in course motivation scores after the implementation. Students exhibited positive attitudes towards robotics and achieved a good level of success. Additionally, a significant effect of motivation on attitudes towards robotics was observed. Gender was found to have no effects on motivation, attitude, or achievement. It was determined that students held positive attitudes towards robotics and developed favorable views of their robotics skills. The implications are discussed in terms of theoretical insights, practices and directions for further research.

Keywords Secondary education · Educational robotics · Gender studies · Course motivation

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1 Introduction

Today, technology has been rapidly developing in all areas of life, and the production of functional technologies in various sectors has become increasingly important. In the 21st-century, when technology is at the heart of life, it is emphasized that students, from early childhood, need an education that enables them to use computer sciences effectively and also develop their production-oriented and collaborative skills (Bers, 2010, 2019; El-Hamamsy et al., 2021a; Kazakoff et al., 2013; Settle & Perkovic, 2010). Fundamental skills such as problem-solving, creativity, algorithmic and computational thinking, necessary for computer experts and people of all ages, professions, and fields, are emphasized under 21st-century skills (Resnick, 2013; Shin et al., 2013; Wing, 2006). These skills can be imparted through teaching programming and computer science (El-Hamamsy et al., 2021b; Kert et al., 2020; Shin et al., 2013). Accordingly, for the new generation of global citizens to creatively use technology according to their needs, adapt to changing demands and production styles, and remain an active member of a productive technology world, knowledge of programming languages is crucial (Aytekin et al., 2018; Cross et al., 2016).

Various platforms (such as Alice, Blockly, Code Org, Scratch, Mblock, and KoduLab) exist to facilitate teaching programming skills to young students. Most of these tools, which are often free, enable individuals to easily develop programs using drag-and-drop or puzzle-like techniques. Such platforms are also referred to as block-based programming environments. These block-based platforms, unlike text-based programming tools with complex code structures, facilitate the learning of algorithms and programming for young students due to their drag-and-drop nature (Bers, 2019; Kert et al., 2020; Strawhacker & Bers, 2015; Todorovska & Bogdanova, 2020). In recent years, studies on educational robotics (ER) applications have also begun to appear in the literature alongside block-based platforms for programming instruction. In ER, robotics education kits containing microcontrollers, various sensors, gears, and motors, such as Lego, Robotis, and VEX, as well as cost-effective, open-source electronic boards like Arduino, different types of motors, and sensors are used. This diversity enriches ER applications with a wide range of tools.

ER provides students with an interactive learning environment that offers hands-on and experiential learning opportunities (Yolcu & Demirer, 2023). The robot-building process is a comprehensive and collaborative endeavor, integrating various disciplines such as mechanics, electronics, and programming. Robotics education encompasses all these processes. Typically, this education covers mechanical components and basic design principles from a mechanical perspective, circuit components and sensors from an electronics viewpoint, and for programming, algorithms, and fundamentals of programming. Students design their robots by following step-by-step guidebooks, in which they familiarize themselves with materials and apply design principles. While working with electronic components, they gain knowledge of basic electronics through microcontrollers and sensors.

Robot programming is a process where developers or end-users create a robot program to implement specific behaviors. In the context of ER, robots are programmed by students. Students can give instructions to make robots behave in a certain way through a user interface like graphical (block-based) or natural language (text-based). The advantage of robot programming is that it provides immediate feedback to students on whether the robot behaves as intended. This prompts students to wonder why the robot behaves in a certain way, ask questions, seek solutions, and solve problems (Bravo et al., 2017). The ability of ER to show the output of developed codes not only on a computer screen but also on a physical robot helps students concretize abstract concepts and code structures. It positively affects their motivation by allowing them to immediately see the real-life impact of their programmed applications (Kert et al., 2020; Ntourou et al., 2021; Sisman et al., 2021; Stewart et al., 2021; Wu & Chen, 2021).

In ER activities, students experience design and implementation processes similar to those of an engineer (Carro et al., 2021; Jackson et al., 2021). ER processes closely mirror the engineering steps followed in a real robot development process. The engineering design process involves developing a system, component, or process to meet specific needs (ABET, 2015). Students who experience these processes can gain engineering design skills. Although the engineering design process is described in the literature with various names and stages, it fundamentally includes similar phases. According to the Next Generation Science Standards [NGSS] (2013), these stages are defining the problem, doing research, identifying needs, generating alternative solutions, selecting and developing the best solutions, creating a model, testing, and making necessary corrections. The engineering design process, considering younger age groups, is built on a six-stage cycle: (1) ask, (2) imagine, (3) plan, (4) create (5) test & improve (6) share (Fig. 1).

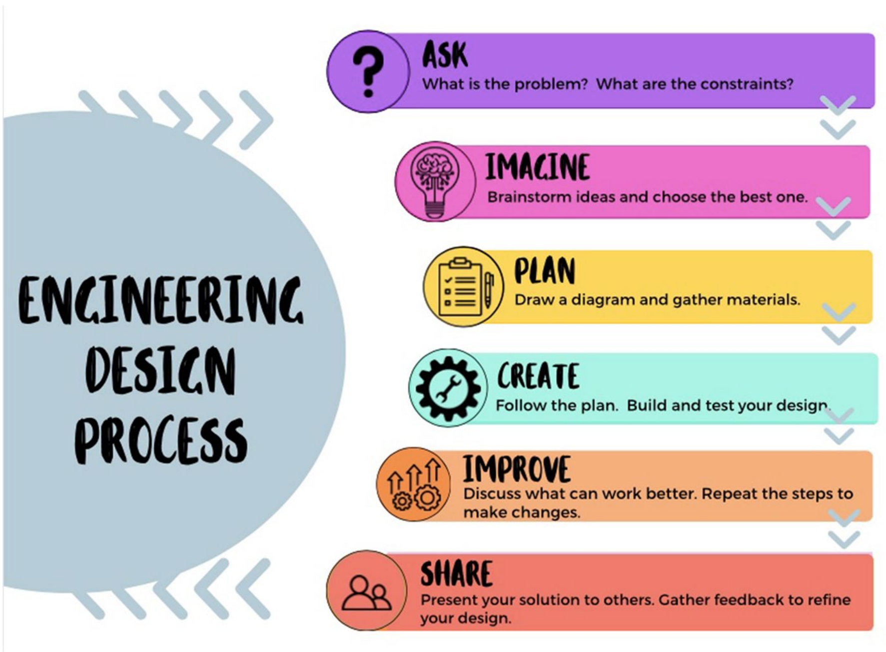

Fig. 1 Engineering design process

Engineering activities and goals are valuable and inherently motivating because individuals are naturally driven to make things and benefit from curiosity about how things work (Brophy et al., 2008). Rogers and Portsmore (2004) state that reducing engineering to elementary school age is based on constructivist philosophy; according to this philosophy, students learn better while working with materials that allow them to design and construct meaningful artifacts for people. In this study, lesson plans based on the engineering design process provided in Fig. 1 above were used. Thus, it aimed to ensure that students adopt engineering design processes as a lasting learning experience.

1.1 Theoretical background

Although ER has only recently become widespread, its origins date back much further. ER applications are based on constructivism and constructionism theories. The views of Piaget (1973) and Papert (1980), suggesting that children in the learning process are not passive recipients but actively construct their knowledge, have been influential in the field of ER. Active thinking and practical activities during the learning process enable learners to create concepts and rules (Ackermann, 2001; Alimisis, 2013; Harel & Papert, 1991). Constructionism emphasizes student-centered learning through the exploration of concrete objects and the importance of connecting prior knowledge and new information in the real world (Alimisis & Kynigos, 2009). Based on this perspective, students are introduced to programming education and engineering practices from an early age through ER (Arís & Orcos, 2019; Berland & Wilensky, 2015; Bers, 2010; Bers & Portsmore, 2005; El-Hamamsy et al., 2021b; Elkin et al., 2016; Kazakoff et al., 2013; Sullivan & Bers, 2018). Current studies in the field of ER are of significant importance. This study investigates the effects of ER on secondary school students' motivation, attitudes, and achievements.

In many studies in the field of education, students' success and failure are often explained through the concept of motivation (Fryer & Bovee, 2016; Gabrielle, 2003; Guilloteaux & Dörnyei, 2008). Learners' motivation is crucial in the learning and teaching process. Accordingly, focusing on the use of technology has been a key approach in research aimed at increasing motivation in the classroom and assisting students (Di Serio et al., 2013; Huitt, 2001). Compared to those lacking motivation, these studies have revealed that students willing to learn tend to participate more, show perseverance, and complete tasks. On the other hand, a lack of motivation in students has been identified as leading to lower their academic performance and even to increase their academic failure (Molaee & Dortaj, 2015). Learners' motivation occupies a pivotal role in the learning and teaching process (Keller, 1987, 2009). Although many researchers have suggested that ER can enhance learners' motivation for learning, entertainment and interaction alone, if only emerging from the technology itself without integrated teaching strategies, cannot sustain learning motivation, which may rapidly decline over time. Numerous studies have identified a close relationship between the sustainability of learning motivation and teaching strategies. In this context, learners should be well directed with suitable teaching strategies to increase and maintain their learning motivation. In other words, introducing ER to learners may boost learning motivation at the start of learning activities, but appropriate teaching strategies are essential (Hung et al., 2013).

Numerous studies have been conducted to date explaining how motivation can be provided, developing various theories in the process. However, most of these theories describe how motivation occurs and on what it depends. Distinctively, the ARCS (Attention- Relevance- Confidence- Satisfaction) motivation model, proposed by John Keller (1987), is a model that facilitates both the provision and sustainability of motivation. The ARCS motivation model offers the opportunity to design the motivation process as a whole by synthesizing motivational theories and concepts. The "Attention, Relevance, Confidence, and Satisfaction" (ARCS) motivation model, a teaching strategy developed to motivate students, focuses on both intrinsic and extrinsic motivations to increase students' motivation and interest (Keller, 1987). According to research, each component of the ARCS model plays a critical role in enhancing students' motivation during the learning process (Di Serio et al., 2013). Yıldız et al. (2019) in their study, indicate that there is a substantial body of work on this model in technology-related fields (computer-web based training, mobile learning, virtual worlds, etc.), and accordingly, instructional designs based on technological areas improve students' academic achievement, motivation levels, and motivational characteristics. This study has been conducted by applying the ARCS model to investigate the impact of ER activities on secondary school students' course motivation, thereby contributing to the limited literature on the use of ER within the framework of the ARCS model.

Student attitudes are also one of the key factors affecting the learning process. Factors such as students' level of maturity and readiness, interests, needs, attitudes, and values can affect their willingness to learn (Tay & Akyürek Tay, 2004). Attitudes express an individual's positive or negative learned predispositions towards an object or concept. Studies have shown that there is a significant relationship between students' academic achievements and their attitudes (Mohd et al., 2011; Nicolaidou & Philippou, 2003). In skill development processes across various sectors, students' attitudes and interests play a critical role. Attitudes often encompass a wide range of emotional behaviors including preference, acceptance, appreciation, and commitment, and are frequently used to express students' intrinsic values or areas of interest (Welch, 2010). In course design, it is important to identify students' attitudes towards the course and the factors affecting these attitudes.

1.2 Literature review

The interdisciplinary nature of ER enables students to find links between different subjects and have a more comprehensive understanding of these subjects as a whole. In this way, ER offers a more extensive and integrated approach in education (Sun & Zhou, 2023). Studies on ER have seen a significant increase in recent years. Many of these studies focus on the instruction of robotics and its inclusion in STEM (Science, Technology, Engineering, Mathematics) processes (Anwar et al., 2019; Atman Uslu et al., 2022; Jung & Won, 2018; Karim et al., 2015;

Zhang et al., 2021). The use of educational robots in teaching processes provides significant positive effects. These effects include the development of computational thinking skills (Sapounidis et al., 2023; Wu & Su, 2021; Zhang et al., 2021), enhancement of problem-solving and creative thinking abilities (Arís & Orcos, 2019; Karim et al., 2015; Zhang & Zhu, 2022), promotion of positive attitudes towards courses (Erol et al., 2023; Hussain et al., 2006; T.T. Wu & Chen, 2021), and strengthening of motivation (Arís & Orcos, 2019; Carro et al., 2021; Erol et al., 2023; Ribeiro et al., 2008; Sáez López et al., 2020; T.T. Wu & Chen, 2021). The integration of ER into STEM education plays a significant role in enhancing students' problem-solving abilities and teamwork skills (Arís & Orcos, 2019; Erol et al., 2023; Kucuk & Sisman, 2020; Ouyang & Xu, 2024; Stewart et al., 2021). Moreover, ER increases interest and participation in the STEM field, positively affecting students' attitudes towards STEM disciplines (Atman Uslu et al., 2022; Chen & Chang, 2018; Erol et al., 2023; Karim et al., 2015; Kim & Lee., 2016; Ouyang & Xu, 2024; Stewart et al., 2021). The focal points of studies that examine ER from different angles and offer various perspectives are summarized in Table 1.

Furthermore, ER is used to facilitate a faster understanding of abstract concepts and to allow the visual and physical application of computer science concepts, thereby enhancing programming and IT skills (Angeli & Valanides, 2020; Atmatzidou & Demetriadis, 2016; Noh & Lee, 2020). Erol et al. (2023), in their study investigating the impact of robotic activities with Arduino on students' attitudes towards ICT (Information and Communication Technology) courses and STEM, revealed that robot design activities conducted with Arduino enhance students' attitudes towards engineering and technology within the context of STEM and ICT courses. Furthermore, student feedback indicates that educational robotic activities are fun, engaging, interesting, and hands-on.

However, it is noted that using ER is a more effective method for developing students' algorithm solving, data processing, and basic programming skills, as well as increasing self-confidence, but not necessarily effective for problem-solving skills (Kert et al., 2020). In contrast, students may find robotic activities diverse, challenging, complex, and time-consuming (Erol et al., 2023). Technical issues, limitations of the robot sets used, limited availability of robots outside of class, and restricted time periods throughout the term have also been found to not positively impact class motivation (McWhorter, 2008).

Some studies, carried out in the past years, have shown that boys generally perform at a higher level than girls in terms of computer experience (Papastergiou, 2009), participation in programming and robotics activities (Rusk et al., 2008), and attitude (Baser, 2013). Additionally, there are findings indicating that boys have more confidence and higher achievement in STEM fields (American Association of University Women & Greenberg Lake the Analysis Group, 1994; Comber et al., 1997; Pajares & Schunk, 2001; Wang & Degol, 2017). However, in recent years, this gender gap has been narrowing. ER activities have become a positive and encouraging tool for women, helping to remove societal biases and bridge the gender gap in computer sciences and STEM fields (Atmatzidou & Demetriadis, 2016; Jackson et al., 2021; Sullivan & Bers, 2018). Most recent research in computer sciences suggests that the difference between men and women is not significant (Atmatzidou &

Table 1 Studies conducted from different perspectives on educational robotics

Programming Instruction	**Motivation, Engagement and Participation**
Erol et al. (2023)	Erol et al. (2023)
Yolcu and Demirer (2023)	Stewart et al. (2021)
Cam and Kıyıcı (2022)	Bargagna et al. (2019)
Angeli and Valanides (2020)	Arís and Orcos (2019)
Sáez López et al. (2020)	Atmatzidou and Demetriadis (2016)
Noh and Lee (2020)	Benitti (2012)
Master et al. (2017)	Saleiro et al. (2013)
Yadagiri et al. (2015)	
STEM Learning	**Problem-solving Skills**
Ouyang and Xu (2024)	Zhang and Zhu (2022)
Erol et al. (2023)	Atmatzidou et al. (2018)
Kucuk and Sisman (2020)	Somyurek (2015)
Anwar et al. (2019)	Karim et al. (2015)
Arís and Orcos (2019)	Alimisis (2013)
Chen and Chang (2018)	
Jung and Won (2018)	
Kaloti-Hallak et al. (2015)	
Eguchi (2014)	
21st-century Skills, Collaboration and Teamwork	**Computational Thinking Skills**
Angeli and Valanides (2020)	Sapounidis et al. (2023)
Ouyang and Xu (2024)	Zhang et al. (2021)
Ioannou and Makridou (2018)	S.Y. Wu and Su (2021)
Karaman et al. (2017)	Angeli and Valanides (2020)
Eguchi (2014, 2016)	Kert et al. (2020)
Okita (2014)	Noh and Lee (2020)
Lin et al. (2009)	Chalmers (2018)
Gerecke and Wagner (2007)	Saleiro et al. (2013)
	Bers (2010)
Positive Attitudes Towards the Course	**Interest, Motivation, and Self-Efficacy Towards the Course**
Erol et al. (2023)	Carro et al. (2021)
Yolcu and Demirer (2023)	T.T. Wu and Chen (2021)
T.T. Wu and Chen (2021)	Sáez López et al. (2020)
Chang and Chen (2020)	Arís and Orcos (2019)
Hussain et al. (2006)	Ribeiro et al. (2008)

Demetriadis, 2016; Noh & Lee, 2020). Studies on gender in ER and STEM show that gender does not affect STEM attitudes (Kucuk & Sisman, 2020), and both genders can have a successful and beneficial experience in ER activities as well as in STEM and computer sciences, without gender being a limitation (Beisser, 2005; Cheng et al., 2013; Hussain et al., 2006; Kaloti-Hallak et al., 2015; Master et al., 2017; Ribeiro et al., 2008).

1.3 Rationale and importance of the study

Software programming influences all aspects of human production and life in the data age, thereby increasingly emphasizing the value of programming education (Sun & Zhou, 2023). Moreover, programming has been redefined as part of the new K-12 computer curriculum reform worldwide. The OECD (2016) states that programming ability is no longer just essential for computer professionals but also a fundamental skill for children living in the intelligent era of the twenty-first century. This situation highlights the importance of providing students with a broader capacity for thinking and the ability to interact with technology.

In programming instruction, the challenge of concretizing often abstract concepts encountered by students can impact their attitudes towards programming and their learning motivation (Anwar et al., 2019; Erol et al., 2023; Hodges et al., 2020; Jdeed et al., 2020; Jung & Won, 2018; Kert et al., 2020; Kim & Lee, 2016; Sisman et al., 2021). Indeed, attitude and motivation are among the most important factors affecting learning (Bixler, 2006; Malone, 1981; Tay & Akyürek Tay, 2004;).

Research indicates that ER activities play a positive role in learning, foster creative thinking, and enhance problem-solving skills (Zhang & Zhu, 2022). Interaction with robots also increases motivation, engagement, and attitudes towards education (Erol et al., 2023; Ouyang & Xu, 2024; Yolcu & Demirer, 2023). Moreover, the simplification of robot design and assembly processes, the inclusion of visual drag-and-drop programming, and the decreasing cost of educational robot platforms are ushering in a new era for educational technologies (Karim et al., 2015).

The benefits and advantages provided by ER applications, such as their interdisciplinary relationship, the various skills gained during the learning process, assistance in concretizing abstract concepts, and the immediate observation of programming outputs on robots, make creating effective learning environments with robotic activities appealing. Ouyang and Xu (2024) emphasize in their study that to fully realize the potential of educational robotics, it's necessary to go beyond focusing solely on robotics itself. The study highlights the importance of integrating interdisciplinary approaches and diverse educational strategies in the development and design of ER applications, in a manner that can maximize learning effects technologically. However, studies on a curriculum integrated with motivation-based ER are quite limited in the literature and on the agendas of many countries (El-Hamamsy et al., 2021a). Within this study, a teaching program has been developed using the ARCS motivation model, which emphasizes the motivational aspect of instruction and highlights the importance of the motivation factor at every stage of teaching. Important cognitive-affective variables such as motivation, achievement, and attitude have been examined. The study sought answers to the following research questions in a 6th-grade Information Technologies and Software course in which educational robotics applications were implemented:

RQ 1. What are the levels of students' course motivation, robotics attitudes, and achievements?

RQ 2. What is the effect of educational robotics applications on students' course motivation?

RQ 2.a. Is there a significant difference between pre-test and post-test motivation scores according to students' initial motivation levels for the course?
RQ 3. Does students' course motivation show any significant differences according to gender?
RQ 4. Do students' achievements and robotics attitudes show any significant differences according to their course motivation levels and gender?

2 Method

In this study examining the impact of educational robotics applications on secondary school students' course motivation, achievements, and attitudes towards robotics, the pre-test-post-test single-group experimental design model, which is a pre-experimental method of quantitative approaches, has been utilized. In this design, the effect of the experimental procedure is tested on a single group. Measurements related to the dependent variable for the subjects are obtained before the procedure as a pre-test, and afterward as a post-test, using the same subjects and the same measurement tools (Creswell, 2014; Fraenkel et al., 2018). The study investigates students' course motivation before and after the experimental application. Additionally, students' attitudes towards educational robotics and learning performance have been revealed following the experimental application.

2.1 Participants and the research process

The study group consisted of 112 sixth-grade students (49 girls, 63 boys, aged 11–12) from four different classes of a state school in a socio-economically disadvantaged area. These sixth-grade students had previously attended a two-hour weekly Information Technologies and Software course in the fifth grade, where they were introduced to basic information technologies and computer literacy skills. In the first term of the sixth grade, they were taught coding using the block-based Scratch program. In the second term, ER applications were conducted for 12 weeks as a part of this study. Parental consent was obtained from the students' parents before starting the study, and ethical committee approvals were secured from the relevant institutions.

In the implementation, daily plans and class activities, prepared within the framework of "ARCS Motivation Strategies" and the "Engineering Design Process", included both programming concepts such as loops, variables, and robotics learning outcomes. The lesson content and plan flow were implemented after receiving expert opinion. For the implementation, an Arduino education kit capable of carrying out the activities in the lesson plans was prepared. Robotics materials used during class activities, including Arduino Uno R3, breadboard, LED, resistor, RGB LED, buzzer, LDR sensor, ultrasonic distance sensor, potentiometer, and jumper cables, were placed in a hobby box, with one set provided for every two students. The pairs were attentively formed to create heterogeneous groups in terms of ability, gender, achievement, and personal characteristics, to integrate students with low skills and learning difficulties into the learning process and also to develop higher learning skills. This approach aimed to increase efficiency by promoting collaboration in groups while maintaining students' motivation and attention in classes. The bi-weekly two-hour lesson plans prepared by the researchers, based on ARCS principles and strategies and steps of the engineering design process, were finalized after being reviewed by two field experts. Table 2 displays an example two-hour weekly plan. The implementation of this plan, including the "Let's Light an LED Activity" circuit diagram and codes, is shown in Fig. 2. Images from the implementation process are presented in Fig. 3.

2.1.1 Data collection instruments

In the research, the Course Interest Scale, Robotics Attitude Scale, and Achievement Test were used as data collection tools. Details of each data collection instrument are provided below.

2.1.1.1 Course Interest Scale (CIS) The Course Interest Survey (CIS), originally published by Keller (2009), has been adapted into Turkish by Dincer (2015). Based on the ARCS Model, the original version of the CIS is a 34-item Likert-type scale (very true, true, moderately true, slightly true, not true) developed to encompass the components of attention, relevance, confidence, and satisfaction, which are the four sub-dimensions named identically to the components of the ARCS Model. In the ARCS motivation model, the attention category involves arousing and sustaining curiosity and interest (Sample Item 4: "There were many things in this course that caught my interest"), the relevance category addresses situations related to learners' needs, interests, and motivations (Sample Item 18: "The content of this course was relevant to my expectations and goals"), the confidence category is about creating a positive expectation of success among learners (Sample Item 3: "I was confident I would succeed in this course"), and the satisfaction category includes providing intrinsic and extrinsic supports to encourage student effort (Sample Item 10: "Learning the topics of this course was satisfying"). The original scale's Cronbach Alpha internal consistency coefficient is 0.95, while the adapted scale's Cronbach Alpha internal consistency coefficient is 0.91. The data obtained indicate that the adapted scale is a valid and reliable instrument for application among middle school students. The scale, which has a midpoint of 96, determines the lowest possible score as 32 and the highest as 160. Based on this information, it is recommended that the scoring and interpretation of the CIS and its sub-dimensions should be conducted according to the principles of normal distribution, within these specified lower and upper limits. Interpretations of the CIS scores and its sub-dimensions are shown in Table 3.

2.1.1.2 Robotics Attitude Scale (RAS) In the study, to determine students' attitudes towards ER activities, the Robotics Attitude Scale (RAS), developed by Cross et al. (2016) and adapted to Turkish by Sisman and Kucuk (2018), was used. The scale consists of four sub-dimensions: learning desire, self-confidence, computational thinking, and teamwork, and includes 24 items in a 5-point Likert format. The Cronbach Alpha value of the scale has been calculated as 0.932.

Table 2 Sample of educational robotics application plan.

Robotics Activities	Description Course Delivery (Learning-Teaching Process)	ARCS Principles and Strategies	Engineering Design Process Method (Activities)
Activity 2.1: Let's Light an LED Activity 2.2: Traffic Light	The students are introduced to what an LED is and are informed about the various fields where LED technology is used. The connection of the LED with Arduino Uno and other circuit components is explained. During the course, students engage in two activities: In the first hour, the "Let's Light an LED" activity, integrated with ARCS principles and strategies, is conducted. In the second hour, the "Traffic Light" activity is carried out, applying the steps of the Engineering Design Process. The concept of loops is explained to the students. Students are shown how to create a loop statement using code blocks. Students are taught how to determine how many times or under what conditions their created loop should continue. Using Mblock, students write codes and are shown how to upload these to the Arduino.	**ATTENTION** Perceptual Arousal (How can I capture the students' attention?) A LED is shown in the class and passed around from hand to hand, asking students what it is to draw their attention. **RELEVANCE** Goal-Orientedness (How can I meet the educational needs of the students?) The teacher explains what they will be able to do at the end of the lesson and directs students towards the learning outcomes of the course. Familiarity (How can I relate what students are going to learn with their prior knowledge?) Students are asked about the lighting systems used and whether they have noticed indicator lights in electronic devices, telling them these are LEDs, thus relating their previous knowledge with the activities they will do. **CONFIDENCE** Learning Requirements (How can I inform students about the required prerequisites and what they will learn?) Students are assured that they have sufficient prior knowledge for the activities in this lesson and that they will be able to successfully complete the activities. **SATISFACTION** Extrinsic Reinforcement (How can I reward the students' achievements?) Students are encouraged and praised for their work during the activities. For example: "Well done", "You can do even better", "You're amazing", etc.	Students work in pairs of two for the activities. In Activity 2.2, the steps of the engineering design process are applied as follows: The teacher describes a scenario where people in a play park reach platforms with small battery-operated vehicles, but as the park gets crowded, accidents occur due to vehicles colliding on intersecting paths. The teacher then poses a problem statement: "How can we prevent these accidents?" **Ask:** In this step, the teacher guides the students to ask appropriate questions about alternative methods for solving the problem. **Imagine:** Students are asked to think of possible ways to achieve the goal and design accordingly. In this context, the teacher gathers the students around the idea of creating a traffic light. **Plan:** Students plan their traffic light circuit in detail using the materials they have. **Create**: Students build a working version of the traffic light circuit they have planned. **Test & Improve:** The created circuit is tested to see how well it meets the intended goal. It is checked whether it would work with different connections or codes. **Share:** In this step, the student shares the activity they have done with the class and receives feedback.

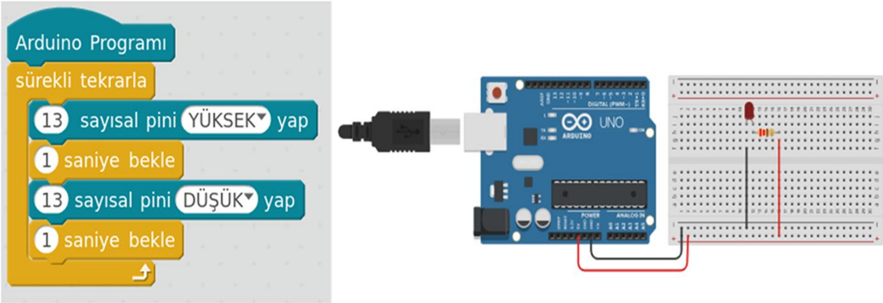

Fig. 2 LED lighting activity Mblock codes and circuit diagram

The scale includes a dimension for Learning Desire, which aims to uncover students' curiosity and interest in robotics with items such as "I want to learn more about robotics" and "robotics interests me." In the Confidence dimension, items like "I believe I can become an expert in the field of robotics" and "I can build a robot" are designed to assess students' belief in their ability to build and program robots. The Computational Thinking dimension includes items such as "I am good at logical thinking" and "I solve problems in a logical way" to reveal students' approaches

Fig. 3 Images from the application process

Table 3 Lower and upper score ranges for CIS and its sub-dimensions

Dimensions	Very Low	Low	Medium	High	Very High
Attention	8.00–9.25	9.26–13.25	13.26–34.74	34.75–38.74	38.75–40.00
Relevance	9.00–10.25	10.26–14.75	14.76–39.24	39.25–43.74	43.75–45.00
Confidence	7.00–8.00	8.01–11.49	11.50–30.50	30.51–33.99	34.00–35.00
Satisfaction	8.00–9.25	9.26–13.25	13.26–34.74	34.75–38.74	38.75–40.00
CIS	32.00–36.00	36.01–52.00	52.01–139.99	140.00–155.99	156.00–160.00

to solving problems they encounter. Lastly, the Teamwork dimension contains items like "I can communicate my ideas to my group" and "I enjoy working in a group" to determine students' views on working in group settings.

2.1.1.3 Achievement test To measure students' achievements in educational robotics applications, the researcher developed an achievement test and a practical exam consisting of multiple-choice and fill-in-the-blank questions. The achievement test encompasses the outcomes of "Problem Solving, Programming, and Original Product Development" units in the Information Technologies and Software Course, as well as the outcomes associated with robotics applications aligned with these goals. These outcomes were selected based on a review of existing literature, consultations with subject matter experts, and findings from preliminary studies to comprehensively understand the effects of ER applications on student achievement. The outcomes were structured around four main components: loops, conditions, variables in programming, and robotics achievements. These outcomes were included in the achievement test after necessary adjustments based on the feedback of three field experts. A pool of items, mostly at the comprehension and application levels, was created for the achievement test, which included multiple-choice and fill-in-the-blank questions. In addition to the achievement test, the researchers prepared a practical exam for each class, consisting of two questions per class, eight questions in total. These practical questions, related to everyday life, were posed to students as real-life problems, with the expectation that they would approach them solution-focused and solve them using their learned robotics knowledge. The practical exam was assessed through a practice control form prepared based on the defined outcomes. Students' achievement scores were calculated by averaging the scores obtained from the achievement test and the practical exam.

Feedback for the achievement test was sought from different field experts such as a measurement and evaluation expert for the content and face validity, four Information Technology teachers for content and content and structure, and two language teachers and two subject matter experts for language review. The expert group reviewed the prepared achievement test in terms of content, learning outcomes, and language. Based on their feedback, some questions in the item pool were revised, and changes were made to the options and stems of the items. As a result, the achievement test included 12 multiple-choice and 3 fill-in-the-blank questions. The test was scored out of 100 points, and the grading was done in accordance with the Ministry of National Education's directive: "85–100—Excellent," "70–84—Good," "60–69—Medium," "50–59—Pass," and "0–49—Fail."

2.1.2 Data analysis

In the analysis of the collected data, the SPSS.21 software was used to initially conduct descriptive statistics such as frequency, percentage, mean, and standard deviation. In the study, dependent t-tests, independent t-tests, and multivariate analysis of variance (MANOVA) were performed upon meeting the assumptions for each test (Field, 2009). A significance level of 0.05 was used for all statistical analyses. The distributions of the data, examined through skewness and kurtosis coefficients, indicated that all variables fell within the + 1 to -1 range, suggesting a normal distribution of the data (Tabachnick & Fidell, 2007). Effect size values in the study were calculated and presented using Cohen's d and η^2. Cohen's effect size values are interpreted as Small: 0.20, Medium: 0.50, and Large: 0.80. In MANOVA tests, partial η^2 values of 0.01 indicate a low effect size, 0.06 a medium effect size, and 0.14 and above a large effect size (Cohen, 1988).

3 Findings

3.1 Students' motivation, achievement, and attitudes towards robotics

The descriptive data related to students' course motivation, achievement, and attitudes towards robotics at the end of the application are presented in Table 4. As seen in Table 4, it has been found that students' motivation towards the course (M = 120.47, SD = 22.6) and their achievements (M = 69.35, SD = 10.17) are at a medium level. Students' attitudes towards robotics have been determined to be at a good level (M = 3.54, SD = 0.74).

3.2 Comparison of pre-test and post-test scores for students' motivation towards the course

A dependent t-test was conducted to determine whether there was a significant difference in the pre-test and post-test average scores of students' motivation towards the course. The results revealed a significant decrease in the students' course motivation scores ($t = 4.36$; $p < 0.05$). The effect size value was found to be 0.39, indicating a moderate level of impact (Table 5).

Table 4 Course motivation, achievement, and robotics attitude scores

	n	M	SD
Course Motivation	112	120.47	22.6
Achievement Score	112	69.35	10.17
Robotics Attitude	112	3.54	0.74

Table 5 Comparison of pre-test and post-test for course motivation

CIS	n	M	SD	t	p	d
Pre-Test Course Interest	112	128.48	18.16	4.36	**0.000**	0.39
Post-Test Course Interest		120.47	22.69			

Additionally, the dependent t-test results, conducted to determine whether there was a significant difference between pre-test and post-test scores in students' initial motivation levels towards the course, are presented in Table 6. The students' motivation levels towards the course were identified based on their responses to the motivation scale administered at the beginning of the term. In this regard, it was determined that 26 students had high motivation towards the course before the implementation, while 86 students had moderate motivation levels.

For the 86 students who initially had a moderate level of motivation towards the course, it was observed that their average motivation scores significantly decreased after the implementation of educational robotics applications (pre-test = 125.23, SD = 18.37, post-test = 112.34, SD post-test = 19.29). The effect size emerged as high at 0.68.

For the 26 students who initially had a high level of motivation towards the course, it was observed that their average motivation scores increased following the implementation (pre-test = 139.23, SD pre-test = 13.34, post-test = 147.38, SD post-test = 4.57). The effect size was high at 0.82.

3.3 Students' motivation towards the course by gender

The results of the independent t-test conducted to determine whether there was a significant difference in students' motivation towards the course based on gender are presented in Table 7. It was found that both male and female students had a moderate level of motivation towards the course (Mean (male) = 121.40, SD (male) = 21.23, Mean (female) = 119.29, SD (female) = 24.63), and that there was no significant difference in course-related motivation by gender ($p > 0.05$.

Table 6 Comparison of pre-test and post-test motivation based on initial motivation levels towards the course

Motivation Level	Tests	n	M	SD	t	p	d
MEDIUM	Pre-test	86	125.23	18.37	5.76	**0.000**	0.68
	Post-test		112.34	19.29			
	Difference in Averages		-12.89	20.77			
HIGH	Pre-test	26	139.23	13.34	-3.36	**0.003**	0.82
	Post-test		147.38	4.57			
	Difference in Averages		8.15	1.79			

Table 7 Motivation level towards the course by gender

Dependent Variables	Gender	n	M	SD	t	p
Motivation Towards the Course	Male	63	121.40	21.23	0.487	0.627
	Female	49	119.29	24.63		

3.4 The impact of students' motivation levels and gender on their achievement and attitudes towards robotics

A Multivariate Analysis of Variance (MANOVA) was conducted to determine if there was a significant effect of students' motivation levels towards the course and their gender on their achievements and attitudes towards robotics. The results are presented in Table 8.

Upon examining Table 8, it is evident that the motivation level towards the course has a significant effect on achievement scores and attitudes towards robotics (Wilks' $\Lambda = 0.704$, $F(2,107) = 3.92$, $p < 0.05$). The effect size is determined to be high at 0.14. It has been found that neither gender nor the interaction of gender with motivation level significantly affects students' achievement scores and attitudes towards robotics.

Table 9 displays the effects of the dependent variables, robotics attitude and achievement scores, in relation to the independent variables of gender and motivation level towards the course. According to the findings from the MANOVA test, while there is no significant effect of motivation level towards the course and gender on achievement scores ($p > 0.05$), the motivation level towards the course significantly affects attitudes towards robotics ($p < 0.05$).

Within the scope of this research question, a second MANOVA test was conducted to investigate which sub-dimensions the significant effect of motivation level towards the course had on attitudes towards robotics. As seen in Table 10, it was found that the motivation level towards the course created a significant difference in the sub-dimensions of attitudes towards robotics (Wilks' $\Lambda = 0.760$, $F(4,107) = 3.92$, $p < 0.05$). The effect size was determined to be 0.24, indicating a high level.

While the motivation level towards the course has a significant effect on the sub-dimensions of attitudes towards robotics, such as desire to learn, confidence, and

Table 8 The effect of motivation level towards the course and gender on achievement and attitude towards robotics

Source of Variance	Wilks' Λ	F	Hypothesis SD	Error SD	p	η2
Motivation Level Towards the Course	0.704	3.92	2.000	107.000	**0.000**	0.144
Gender	0.990	0.20	2.000	107.000	0.854	0.003
Motivation Level Towards the Course*Gender	0.993	0.72	2.000	107.000	0.620	0.009

Table 9 Effects of robotics attitude and achievement as dependent variables on gender and motivation level towards the course as independent variables

Independent Variables	Dependent Variables	Sum of Squares	Mean Squares	F	p	η2
Adjusted Model	Achievement Score	208.903[b]	69.634	0.667	0.574	0.018
	Attitude Towards Robotics	9.403164[a]	3.134	6.614	**0.000**	0.155
Joint Interaction	Achievement Score	391,002.635	391,002.635	3747.296	**0.000**	0.972
	Attitude Towards Robotics	1098.064	1098.064	2317.058	**0.000**	0.955
Motivation Level Towards the Course	Achievement Score	169.085	169.085	1.620	0.206	0.015
	Attitude Towards Robotics	8.633	8.633	18.217	**0.000**	0.144
Gender	Achievement Score	18.734	18.734	0.180	0.673	0.002
	Attitude Towards Robotics	0.029	0.029	0.060	0.807	0.001
Motivation Level Towards the Course * Gender	Achievement Score	0.151	0.151	0.001	0.970	0.000
	Attitude Towards Robotics	0.434	0.434	0.916	0.341	0.008
Error	Achievement Score	11,269.002	104.343			
	Attitude Towards Robotics	51.182	0.474			
Total	Achievement Score	11,477.906				
	Attitude Towards Robotics	60.585				

Table 10 The effect of motivation level towards the course on the sub-dimensions of robotics

Source of Variance	Wilks' Λ	F	Hypothesis SD	Error SD	p	η2
Motivation Level Towards the Course	0.760	8.436	4.000	107.000	**0.000**	0.24

computational thinking ($p < 0.05$), it does not have a significant impact on the teamwork sub-dimension ($p > 0.05$). When examining the magnitude of the significant effect of motivation level towards the course on the sub-dimensions of attitudes towards robotics, it was found that desire to learn ($\eta 2 = 0.190$) has a large effect size, whereas confidence ($\eta 2 = 0.136$) and computational thinking ($\eta 2 = 0.123$) have a medium level of effect size.

4 Discussion and conclusion

This research investigated the effects of an educational robotics program developed with the ARCS motivation model on students' motivation towards the course, their achievements, attitudes towards robotics, and whether gender had any influences on these factors. The implementation conducted for the study revealed that students had a good level of attitude towards robotics and their achievements were also close to being good. However, a more detailed examination of the results showed that despite students' motivation towards the course being moderate both before and after the application, there was a relative decrease in the average motivation scores after the application. The higher level of interest towards the course initially might be due to the block-based Scratch programming studied by the students in the first term of the Information Technologies and Software course and perceived as easier and more enjoyable, thereby motivating and engaging students. However, this study also suggests that creating electronic circuits, encountering new concepts like resistance, sensors, grounding, and resolving wiring complexities could have increased cognitive load and thus, students' motivation decreased. Indeed, studies indicate that students perform better and exhibit higher motivation when using block-based Scratch in programming instruction, as it offers a more engaging learning environment by visualizing program structures (Kert et al., 2020; Bers, 2019; Kazakoff et al., 2013; Resnick et al., 2003; Ruf et al., 2014; Strawhacker & Bers, 2015). Tlili et al. (2017), in their study, implemented a "learning by doing" strategy for undergraduate computer science students and applied Keller's ARCS motivational model. These approaches were observed to increase student motivation, keep them actively engaged, and assist them in acquiring the necessary technical skills to develop their educational games. Keller's ARCS motivational model is designed to increase students' interest in the learning process, strengthen the relevance of learning materials to their personal and professional goals, support their confidence towards success, and maximize their satisfaction from the learning experiences (Keller, 1987). Therefore, although some students found educational robotics activities difficult, there was no significant decrease in their motivation for the course.

Contrarily, Przybylla and Romeike (2014) have noted that while physical programming is seen as an exciting phenomenon by many teachers, the technical complexity of activities like breadboarding and soldering often makes them unsuitable for classroom use. In this study, it was proposed that teachers could solve these problems using ready-made robot sets like MyIG, TinkerKit, Hummingbird, etc. However, it has been observed that the cost of educational robotic activities conducted with these ready-made sets is significantly higher compared to the materials used in this study. Additionally, factors such as students only being able to work during laboratory hours, lack of resources to revise topics outside of class hours, insufficient weekly lesson hours, and large class sizes may have contributed to a relative decrease in students' motivation towards the course. Parallel to this conclusion, similar findings are reported in the literature (Beug, 2012; Fagin & Merkle, 2002; McWhorter, 2008; Reich-Stiebert & Eyssel, 2015). Beug (2012) in his study concluded that Arduino is not suitable for teaching programming concepts at a beginner level, noting that some students in the Arduino group got bored during activities, possibly due to technical difficulties related to the Arduino board. Ouyang and Xu (2024) in their research, showed that ER is more effective at high school and higher education levels compared to other educational levels (e.g., elementary, middle school). Due to the complex functions of ER, it is considered that most educational robotics might be more suitable for older students (e.g., students in higher education) rather than younger ones (e.g., elementary school students).

Fagin and Merkle (2002) associated the negative results of their research with the lack of equipment for robotic students to work with outside class hours. They suggested allowing students to take robots home after class or providing more out-of-class lab time. McWhorter (2008) identified potential reasons for the lack of positive quantitative outcomes in course motivation from robotic activities, including technical problems, limitations of the robot set used, limited availability of robots outside of class, and the restricted time allocated for robotic activities throughout the term.

On the other hand, Saleiro et al. (2013) indicated in their study that robot systems which do not require additional software installation (based on PIC microcontroller, Arduino, or Raspberry Pi and programmed with Blockly) were successfully used even by 3rd and 4th-grade students. Moreover, the use of robotics in education has been found effective in increasing students' willingness to collaborate with each other and in enhancing their desire and motivation for learning activities, as evidenced in various studies (Arís & Orcos, 2019; Atmatzidou & Demetriadis, 2016; Bargagna et al., 2019; Benitti, 2012; Erol et al., 2023; Gupta et al., 2012; Highfield, 2010; Jdeed et al., 2020; Kucuk & Sisman, 2017; Ouyang & Xu, 2024; Ribeiro et al., 2008; Rubio et al., 2013; Sáez López et al., 2020; Stewart et al., 2021; Wei et al., 2011).

When examining the initial motivation levels of students towards the course, it was found that the 86 students with a moderate level of initial interest experienced a decrease in their interest after the implementation, while the 26 students with a high level of initial interest showed an increase in their interest. In other words, for students already highly interested in the course, robotic activities were engaging and enhanced their motivation. Literature review also indicates that many studies on motivation report similar positive outcomes (Arís & Orcos, 2019; Erol et al., 2023; Kaloti-Hallak et al., 2015; Kert et al., 2020; Kucuk & Sisman, 2017; Ribeiro et al., 2008; Rubio et al., 2013; Sáez López et al., 2020; Saleiro et al., 2013).

According to the findings from the robotics attitude scale, students developed positive attitudes towards robotics and their attitudes were found to be at a good level after the application. Consistently, literature also indicates that robotic activities positively influence students' attitudes towards computer sciences and STEM (Science, Technology, Engineering, and Mathematics) fields (Anwar et al., 2019; Arís & Orcos, 2019; Chen & Chang, 2018; Erol et al., 2023; Hussain et al., 2006; Jung & Won, 2018; Kaloti-Hallak et al., 2015; Kandlhofer & Steinbauer, 2016; Kucuk & Sisman, 2020; Liu, 2010; Ouyang & Xu, 2024; Ribeiro et al., 2008; Rubio et al., 2013; Somyurek, 2015; Zhang et al., 2021).

The average achievement scores of students, calculated by combining the results of the success test and the practical exam conducted at the end of the educational robotics activities, are quite close to a good level. The fact that students had learned block-based coding in the first term of this course may have contributed to this outcome. Additionally, students who did not perform well in written exams may have been able to demonstrate their robotic skills more comfortably in the practical exam, which could have had a positive effect on the results.

Another result of the study is the significant effect of motivation level towards the course on attitudes towards robotics. It can be said that students with a high level of motivation towards the course are more interested in the field of computing and its applications. This may have led to the development of positive attitudes towards robotics. Additionally, it was determined that the motivation level towards the course has a significant effect on the sub-dimensions of attitudes towards robotics, including desire to learn, confidence, and computational thinking. However, no significant effects were determined on the teamwork sub-dimension of the robotics attitude. In the ARCS motivation model used in the study, the attention category, by arousing and maintaining curiosity and interest, may have increased the desire to learn. The relevance category, by helping students perceive teaching needs as consistent with their goals, compatible with their learning styles, and related to their past experiences, may have positively influenced their computational thinking. The confidence category, by creating a positive expectation for success, may have positively impacted students' self-confidence. The grouping of students in pairs may not have provided an adequate team working environment, which could be why no effect was observed in the teamwork dimension.

The study also revealed that gender as an independent variable did not have any effects on students' motivation towards the course, their attitudes towards robotics, or their achievement. This finding aligns with previous research in science, mathematics, technology, and engineering activities, where gender differences have been a notable point of discussion. Historically, many studies have highlighted gender differences, showing that males often had more confidence and higher achievement in fields related to science, technology, engineering, and mathematics (STEM) (American Association of University Women & Greenberg Lake-the Analysis Group, 1994; Comber et al., 1997; Pajares & Schunk, 2001; Papastergiou, 2009; Wang & Degol, 2017). Research has also indicated that males generally exhibited higher levels of computer experience

(Papastergiou, 2009), participation in programming and robotics activities (Rusk et al., 2008), and attitudes towards these fields (Baser, 2013) than females.

However, in the last decade, this gender gap has been gradually decreasing. Recent literature suggests that robotics activities attract equal interest from both genders, and gender does not delimitate it. Studies have shown that there are no significant differences in learning outcomes based on gender in the context of robotics (Cheng et al., 2013; Hussain et al., 2006; Jackson et al., 2021; Kaloti-Hallak et al., 2015; Ribeiro et al., 2008; Sullivan & Bers, 2018). This shift may be attributed to various factors, including changes in societal attitudes, more inclusive educational practices, and a broader recognition of the importance of engaging all students, regardless of gender, in STEM fields.

5 Limitations and implications

The limitations of this study include its implementation with a limited number of students over a short period, in a single-group pre-test post-test design at a school with a low socio-economic status. Another limitation is that students' motivation towards the course and their attitudes towards robotics were determined through self-reports. The fact that the educational robotics (ER) activities were conducted only with one type of robotics set might also be considered a limitation. Additionally, the limited classroom hours for students to access ER sets and the lack of such equipment at their homes constrain the further study.

For future research, teaching activities could be designed using different robotics sets. More comprehensive collaborative activities could be planned to foster a team-working spirit among students. Some opportunities could be provided for students to practice more what they learn in class during their out-of-class time. Future studies could examine students' course motivation, achievements, and attitudes towards robotics using larger sample groups and longer-term implementations, including experimental and control group designs. Investigating how students' cognitive and affective states are influenced in environments using different ER sets and various teaching designs would be valuable. Additionally, students' experiences related to the process could be explored more in-depth through qualitative studies, providing a more comprehensive understanding of the impact and dynamics of educational robotics in learning environments.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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