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You are an astroneer: the effects of robotics camps on secondary school students' perceptions and attitudes towards STEM

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Abstract

Creativity, critical thinking, communication and collaboration are thought to be the core skills that will enable students to be successful in the future. Economic and social development of a nation is associated with the individuals' such new skills, which are commonly referred as the twenty-first-century skills. However, the educational methods used in transmitting knowledge from teachers to students are not capable enough to bring up such competent individuals. The "Science, Technology, Engineering, and Mathematics" (STEM) education is a promising approach to help students gain those skills and robotics offers opportunities to integrate STEM education. This study aims to investigate the effects of robotics summer camps with STEM activities on students' perception and attitudes towards STEM. The researchers organized two robotics summer camps in 2017 and 2018 with 48 students. Data were collected by using the STEM Perception Test and STEM Attitude Test. The pre-test post-test quasi-experimental design without a control group was used in the study. Wilcoxon's Matched-Pairs Signed-Ranks tests showed that students' perceptions towards STEM increased at the first robotics camp; however, students' attitudes towards STEM did not change significantly in both robotics camps. Furthermore, mathematics sub-dimension of STEM perception at the first camp and science sub-dimension of STEM attitude at the second camp significantly increased.

Keywords Robotics camp · STEM · Perception · Attitude · Secondary school students

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Introduction

Individuals in the information age should have knowledge and skills other than reading, writing, and mathematic. The organizations such as "Partnership for 21st Century Skills (P21)" (2009) and "Assessment & Teaching of twenty-first-century Skills" have identified the knowledge and skills that twenty-first-century students should have. The most important four skills were identified as "creativity", "critical thinking", "communication" and "collaboration" and acknowledged as the "Four C's" (Eguchi, 2014; National Education Association (NEA), 2012). STEM (Science, Technology, Engineering, and Mathematics) education offers an opportunity to instil these skills into the students (Bybee, 2010b; Tang & Williams, 2019). The existing lack of interest among the students on STEM topics will continue to grow and the need for qualified individuals in the STEM professions will increase in the future (The United States Department of Education (TUSDE) 2016). Science, mathematics, engineering, and technology are critical subjects for the economic power of a nation (Corlu et al., 2014; Kelley & Knowles, 2016; National Research Council (NRC), 2011). Nations need to increase both quantity and quality of individuals trained for STEM-related professions (Sahin et al., 2013). Attitudes and perceptions are the two constructs that are significantly related to STEM performance and careers (Knezek et al., 2013; Maltese & Tai, 2011; Wiebe et al., 2018), and robotics has been an effective tool for hands-on learning of, not just robotics related subjects but also STEM subjects (Mataric et al., 2007). Therefore, teachers show high interest on robotics to develop learners' cognitive and social skills (collaboration, cooperation, and communication skills) and for better learning of STEM subjects in hands-on, fun, and attractive learning environments (Alimisis, 2013; Eguchi, 2016; Kim et al., 2015). This paper aims to present the effects of robotics summer camps with STEM activities on the secondary school students' perception and attitudes towards STEM. Therefore, in the following literature review section, firstly attitude and perception concepts are defined. Afterwards, STEM education and its importance were explained and studies on the use of robotics in STEM education were summarized.

Attitude and perception

Educators are interested in attitudes because of their potential effects on learning. Attitudes toward STEM are associated with motivation to learn STEM subjects and pursuit of a STEM career (Maltese & Tai, 2011). However, the word "attitude" has been a controversial concept (Simonson & Maushak, 1996) and has been described in many ways (Maio et al., 2018; Simonson & Maushak, 1996). Zimbardo and Leippe defined attitude as: "An evaluative disposition toward some object-based upon cognitions, affective reactions, behavioural intentions, and past behaviours" (1991, p. 31). The object in the definition could be individuals, groups of people, social issues, behaviours, abstract ideas, and specific objects (Maio & Haddock, 2004). Ajzen made the definition of attitude as "a disposition to respond favourable or unfavourable to an object, person, institution or event" (2005, p. 3). Both attitude definitions underline somebody's evaluative assessment of an object (Maio et al., 2018; Thibaut et al., 2018). Attitude is a hypothetical construct like personality trait since it is inaccessible to direct observation, which must be inferred from measurable responses (Ajzen, 2005). Meanwhile, perception is defined as "the process of organizing and interpreting sensory information, enabling us to recognize meaningful objects and events" (Myers & DeWall, 2018, p. 214). When a person is confronted with a situation or stimuli, the person interprets the stimuli into something meaningful to him or her based on previous experiences. Perception is the process of recognition and interpretation of sensory information from the environment, while attitude is a general evaluation of situations and define how we behave toward the situation or object (Pickens, 2005).

Integrated STEM education

The acronym STEM stands for the disciplines of science, technology, engineering, and mathematics but the definition of STEM education referenced in studies continues to vary. The definition emphasizes only one discipline in some cases; while, the disciplines are assumed separate but equal, or STEM education is considered as an integration of these four disciplines (Bybee, 2013) on some others. STEM education can simply be defined as integrating science, technology, engineering, and mathematics subjects in the curriculum (Corlu et al., 2014; Scott, 2009). Integration of these four disciplines create a final product greater than the sum of science, technology, engineering, and mathematics (Páez et al., 2019). A more detailed definition of STEM education could be "an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy" (Tsupros et al., 2009). Thibaut et al. (2018) conducted a narrative review to define key principles for integrated STEM education. They defined the five STEM principles as integration, problem-centered learning, inquiry-based learning, design-based learning, and cooperative learning. Integration, the first principle, refers to integrating contents from different STEM disciplines. The second principle, problem-centered learning, emphasizes using a real-world problem to create an engaging and motivating context. The third principle, inquiry-based learning, is not limited only to science inquiry, but also refers to questioning, discussing, interpreting, using, and attempting to understand mathematical or technological ideas. The fourth one, design-based learning, means use of engineering or technological design, and the last one, cooperative learning, emphasizes teamwork and collaboration with others in small group works.

STEM education aims to provide individuals with an interdisciplinary perspective on problems, knowledge, and skills (Sahin et al., 2013). Therefore, students dealing with STEM activities realize that STEM is everywhere and they learn to take a team-based approach to tackle with real-world problems through applying their science, technology, engineering, and mathematics knowledge (Beers, 2011; Bybee, 2010b; Tanenbaum, 2016). By dealing with STEM activities, students develop twenty-first-century skills such as systems thinking, social skills, adaptability, complex communication, non-routine problem solving, self-management/self-development, which allows them to make better decisions on their personal health, quality of the environment, use of resources, energy efficiency, and national security (Bybee, 2010a, 2010b). Besides, a country's scientific leadership and economic growth are associated with the promotion of STEM education and raising awareness of the profession in STEM fields (Sahin et al., 2013). Moore (2008) states that the aim of the integrated STEM education is (a) to deepen students' understanding of each discipline through the contextualization of concepts, (b) to expand students' understanding of STEM disciplines via exposing them to socially and culturally relevant STEM contexts, and (c) to increase interest in STEM disciplines to expand the pipeline of students entering the STEM fields.

Educational robotics in STEM education

The interest of educational communities in robotics has grown at an amazing rate in the last decade (Benitti, 2012; Ioannou & Makridou, 2018). Robotics can be used in education in a variety of ways and purposes. It could be categorized either as “robotics in education” or as “robotics for education” (Malec, 2001). Alimisis and Kynigos (2009) also made similar categorization of robotics for educational usage as “robotics as learning object” and “robotics as a learning tool” (p. 17). The first category, either called as “robotics in education” or “robotics as learning object”, includes learning activities in which robot and robot-related subjects are the target of teaching. Robot construction, artificial intelligence, robot programming are the focus of instructions and are usually prepared for university-level learners. In the second category, robotics is used as a teaching and learning tool for school subjects, usually in interdisciplinary, project-based learning activities of science, math, informatics, and technology (Alimisis & Kynigos, 2009; Malec, 2001). Using robotics as a learning tool in the classroom can also be called “educational robotics” (Eguchi, 2017, p. 9).

Educational robotics is a particular implementation of K-12 engineering education, and offers convenience to work with physical manipulative for participating in the engineering design process (Ortiz et al., 2015). Educational robotics helps create a fun and engaging hands-on learning environment for learners (Ding et al., 2019; Eguchi, 2014; Gura, 2012; Mataric et al., 2007). Working with robotics requires students to deal with manipulating, assembling, and reassembling materials during designing and programming their robots unlike a traditional classroom setting where students mostly listen lectures. Therefore, problem-based, project-based, design-based, student-centered, and constructionist learning are learning approaches that can be used when dealing with robotics (Eguchi, 2017).

The idea of using robotics in education has its root in the studies of Seymour Papert known as the founding father of Logo programming language (Papert, 1993). The theoretical background of Logo programming language and educational robotics is known as Constructionism (Kafai & Resnick, 1996) and developed by Papert. Papert got inspired by Piaget’s way of looking at children as the active builders of their own intellectual structures, and built his theory on Piaget’s constructivist theory (Papert, 1993). Like in constructivism, the Constructionist approach considers children as the active builder of their knowledge rather than passive receivers of the knowledge from teachers. However, constructionism adds extra emphasis to “external artifacts” and “sharing with others” (Kafai & Resnick, 1996; Maxwell, 2006).

Robotics has been used in education for different purposes, such as computational thinking skills (Chalmers, 2018; Chen et al., 2017; Leonard et al., 2016a; Taylor & Baek, 2019), programming skills, attitude towards programming, and programming motivation (Ortiz et al., 2015; Taylor & Baek, 2019), behavioral patterns (Kim et al., 2015; Kucuk & Sisman, 2017), creative behaviour (Nemiro et al., 2017), problem-solving skills (Li et al., 2016; Ortiz et al., 2015), robotics performance (Chen et al., 2017; Taylor & Baek, 2019), and attitude towards robots (Castro et al., 2018; Reich-Stiebert et al., 2019). Additionally, robotics has become a new perspective for teaching STEM subjects with hands-on experience and an effective tool for facilitating students’ STEM learning (Eguchi, 2017; Jim, 2010). Robotics-based pedagogy provides at least five key advantages over traditional pedagogy in teaching the theory and practice of STEM; (a) robotics could integrate STEM topics in a multidisciplinary fashion,

(b) efficiently transforms abstract concepts into concrete learning modules for students, (c) combines the STEM theory with its practice, (d) provides hands-on learning that is active and engaging, and (e) offers a highly enjoyable and motivating learning environment (Chung et al., 2014). Benitti and Spolaôr (2017) carried out a systematic literature review to answer the question: how robots have supported STEM teaching. They have selected and reviewed 60 papers related to robotics and STEM education published between 2013 and 2016. The synthesis of the literature has resulted in that: (a) Not only technology and engineering-related subjects but also many STEM subjects were taught by the help of robotics, which shows the flexibility of robots as a learning tool. (b) Teamwork and problem-solving skills were the mostly observed skills. (c) Robots were mainly used in extracurricular activities. (d) Lego robots were the most commonly used robotics kits. (e) Robotic studies were conducted at all educational levels. (f) Twenty five percentage of the studies were used in both qualitative and quantitative approaches.

There are some other studies aimed to evaluate the effects of robotics activities on STEM attitudes and perceptions as well. For example, Kim et al. (2015) investigated pre-service teachers' STEM learning, teaching, and engagement while they were using robotics. Both qualitative and quantitative data analyzes revealed that pre-service teachers' emotional engagement (e.g., interest, enjoyment) in STEM improved significantly and affected pre-service teachers' cognitive and behavioural engagement in STEM. Similarly, Khanlari (2013) conducted a qualitative study with experienced robotics teachers. This study pointed out that robotics helps learners understand STEM subjects and enhances learners' interest in STEM fields.

One of the largest educational robotics study was conducted by Nugent et al. (2016). They collected data from 2409 campers, competition, and club participants during six years. The results of the research revealed that robotics activities increased participants' awareness of STEM content (especially computer programming and engineering), perceived problem-solving skills, and increased the interest in engineering careers. Similarly, Conrad et al. (2018) have conducted a study to evaluate elementary, middle, and secondary school students' perceptions toward STEM content and careers. The data were collected from 211 students, who attended university-based summer robotics camps. The robotics camp was one week (30 h) long, and prepared at different levels from 4 to 12th graders. The participation in the robotics camp was resulted in improvements in the perceptions and feelings of the students about STEM, based on the increase between post- and pre-test results; however, these differences were not statistically significant.

In a summer STEM camp, providing school content in a new environment was a catalyst for a positive change in how the students' perceived future STEM content (Roberts et al., 2018). In addition, previous studies on STEM education showed that attitudes of students towards STEM are critically related to their future interest in STEM fields (Ching et al., 2019). Attitudes and perceptions are significantly related to students' performance in STEM fields (Knezek et al., 2013; Maltese & Tai, 2011; Wiebe et al., 2018). A considerable number of studies have been conducted regarding attitudes towards mathematics and science, but there are fewer studies on attitudes towards technology and engineering (Guzey et al., 2014). Attitudes toward STEM content and career interests are identified as key variables in predicting the student participation in STEM-related careers (Unfried et al., 2015). Studies that are focused on the effectiveness of STEM-focused schools, and out-of-school activities on students' attitudes toward STEM and their STEM performance outcomes are poor in the related literature (Binns et al., 2016).

In this study two robotics camps that enriched with STEM activities were designed and conducted to extend this body of knowledge by measuring and assessing the secondary school students' perceptions and attitudes towards STEM before and after participating in robotics camps. Therefore, the research questions of the study were defined as:

- What is the effect of STEM-related robotics camps on students' STEM perceptions?
- Is there a difference in students' STEM perception between the two robotics camps?
- What is the effect of STEM-related robotics camps on students' STEM attitudes?
- Is there a difference in students' STEM attitudes between the two robotics camps?

Methodology

Robotics camps

Two robotics camps, designed to last in total 48 to 60 h within 8–10 days and with an average of 6 h per day, were conducted to measure the effects of robotics camps on participants' perceptions and attitudes towards STEM. Lego Mindstorms Education EV3 robotics sets were used and the same robotics curriculum was followed in both camps. The students worked in groups of four to five, and each group had its own robotics sets and computers. Besides the instructors in the camps, there were experienced guides in robotics and coding in each group. The guides provided guidance and support for the challenges or problems faced by group members and monitored participants. Details of the two camps in 2017 and 2018 are as follows.

Robotics Camp in 2017 (RC-17). The first robotics camp was carried out in September 2017 in collaboration with the Provincial Directorate of National Education. Robotics camp took place on a university campus. Provincial Directorate of National Education received the required permissions and determined the students to attend the camp. Most of the students were selected from students, who attended the Science and Art Center of the Ministry of Education. The Science and Art Centers aim to ensure that talented students are aware of their individual abilities and use them at the highest level by developing their capacities (MEB, 2016). These students were selected to the Science and Art Center by an entrance exam, and they work on projects there after school. The participants of RC-17 were high-achiever students. Totally, 24 students have attended RC-17, however, 20 students ($M=10$, $F=10$), filled out both pre- and post-tests. One (5%) student was 5th and 1 (5%) student was 6th grade and the rest of them (90%) was 7th grade. Only 2 (10%) students have already had robotic experience and 15 (75%) students had programming experiences (e.g. Scratch or Kodu).

Robotics Camp in 2018 (RC-18). Similar to the first robotics camp, the second camp was carried out in collaboration with the Provincial Directorate of the National Education in September 2018. The second camp took place in a boarding school and the participants of the camp were selected by the boarding school administration. Similar to the first camp, 24 students have attended the second camp. Number of the students who filled out both pre- and post-tests was 21 ($M=8$, $F=13$). Five (24%) students were 6th grade, 11 (52%) students were 7th grade, 4 (19%) students were 8th grade and 1 (5%) student didn't specify grade. None of them had a robotic experience and all participants carried out programming activities with scratch or code.org in the computer lessons they took when they were 5th and 6th grade.

Lego mindstorms robotics kits

Lego Mindstorms Education EV3 Core Set and EV3 Expansion Set were used in both camps. The third generation of the set was released in 2013 and called EV3 (Takacs et al., 2016). EV3 Intelligent Brick, which is a Linux-based compact and powerful programmable computer, is the most important element of the robot kit. The brick can also be programmed without a computer, controls the motors, and collects the data from sensors (https://education.lego.com). EV3 system also includes three servo motors, five sensors (ultrasonic, color, gyro, and two touches) gears, wheels, axles, cables, and other technical parts. The expansion set, shown in Fig. 1 below, contains 853 supplementary structural and mechanical elements for the core set.

Each group of students used a core set during the camps and an expansion set was also distributed to each group, when they worked on their project. By this way, learners had more freedom while designing their robots. Students can get a simple robot up and running in about a half-hour with an EV3 robotic kit (Sansing, 2014). The official LEGO Mindstorms programming environment called EV3 Software was used to program robotic kits. LEGO and National Instrument have developed this GUI-based programming environment for the robotic set (Garber, 2013). EV3 Software is an easy-to-use environment for programming EV3 robotic kits and downloading programs to the robot through a drag-and-drop programming approach (Fig. 2).

This graphic-based programming environment makes programming accessible to young people (Eguchi, 2015). Even novice users can easily program their robots by dragging and placing pre-defined programming blocks on the screen. Each block has a unique function like turning the motors, playing sound, measuring light or distance. Each command is represented with icons and these blocks can be plugged into another to determine the flow of the program. The software supports basic programming construct such as loops and conditions, and more advanced features like parallel execution. The education version of the program also supports data logging. Therefore, real-time or collected data from sensors can be plotted as graphs and analyzed as shown in Fig. 2.

Fig. 1 Lego mindstorms education EV3 core and expansion sets

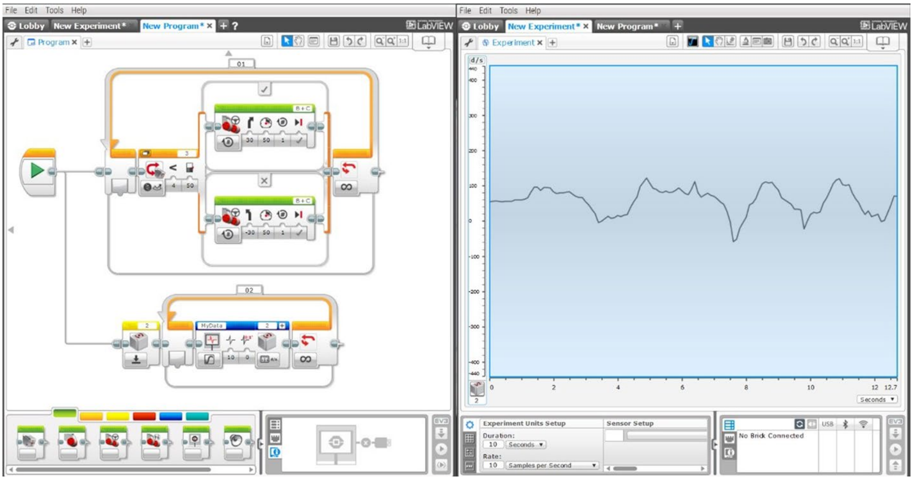

Fig. 2 EV3 programming software interface and data logging screen

Mindstorms robotic kits that can work via USB or Bluetooth connectivity can be programmed with many tools such as ROBOTC, NBC, and NXC (Takacs et al., 2016).

Robotics curriculum

One of the key challenges in STEM education is designing authentic learning scenarios (Hallström & Schönborn, 2019). Kelley and Knowles (2016) stated that researchers need to document in more detail their interventions, curriculum, and programs for further investigation of integrated STEM education. Therefore, the curriculum of robotics camps is presented here. After evaluating all components of kits and software facilities, an appropriate robotics curriculum was designed for STEM training. The activities in the curriculum encouraged students to use their science, technology, engineering, and mathematics knowledge while dealing with them. The robotics curriculum consisted of three main sections; programming, moon station missions and projects. Students were taught to build robots and program them in the programming section. Sherrod et al. (2009) emphasize the importance of allowing students to pretend like scientists and mathematicians to investigate, calculate, and analyze data to solve the problems. Therefore, after the first section of the camp, the students were called **ASTRONEERS** (both **ASTRO**nauts and engin**EERS**), and they began the moon station missions. The missions were given via the website with multimedia support. Moon station missions were like computer games, but they achieved their mission on the activity table in the real world. Then, they entered the code or results of the mission into the website to pass to the next mission. The participants worked on their project in the last days of the camps. At the project session, problem, project, and design-based learning approaches that are highly used techniques in STEM education (Bazzett et al., 2018; Gazibeyoglu & Aydin, 2019; Kelley & Knowles, 2016; Lin et al., 2020; Vennix et al., 2018) were implemented. The students prepared robotics projects to make a solution for a daily life problem. On the last day of the camp, the parents were invited to camps, and the students presented their robots' performance.

In the programming section of the camps, the students received training about assembling the robotic kit and programming. On the first days of the camps, they constructed their robots by following the instructions in the manual. During the programming section, one instructor explained how they could program their robots by using EV3 Software on the board, and each group applied what they had learned with the help of their mentors. Robotics, algorithms, sensors (ultrasonic, colour, touch, and gyro), programming blocks such as move, display, sound, wait, loop, and switch were the key topics of the programming section. Collecting or saving any sensors' data and analyzing these data with the experiment interface of the software were covered in this section. Some competitions were organized to increase the motivation of students in the programming section. For example, when the students had learned to move programming blocks, the radius of the robot's tire was given to students and asked to program their robots to move exactly 3 m. Without any trial and error, they were asked to calculate how much rotation is required for exactly 3 m move and program their robots accordingly. The robot, which would stop closest to the finish line was the winner. Similarly, the line follower robot competition, which aimed to follow a nonlinear black line and reach the finish as soon as possible, and the fastest robot design competition, which required using gears were the other competitions. After the students were trained in robot sets and programming, they carried out the moon station missions.

Moon station missions were based on a scenario, and a website was designed for the missions. Each group had unique login credentials and when they login to the website, they encountered a video explaining the problems caused by meteor showers on the moon station especially on the reactor. The missions of the astroneers were to resolve the issues on the station. Because of the radiation leak, no one could leave the base. Therefore, they should program their robot to resolve the issues.

Figure 3 shows the working area for the moon station missions. The area was printed out on cardboard with the size of 1.5 m × 1 m for each group. Students took their mission from the website and worked on the area to accomplish their missions. When they accomplished the mission, they were required to enter the result to the website to pass the next missions as listed below:

- *Mission 1,* the first mission of astroneers was to gather information about the moon station. They were asked to measure the distances between the base, the power control unit, and the reactor. To accomplish the mission, they could enter the measured values (±2 cm) in the three text boxes specified on the website. The students could not per-

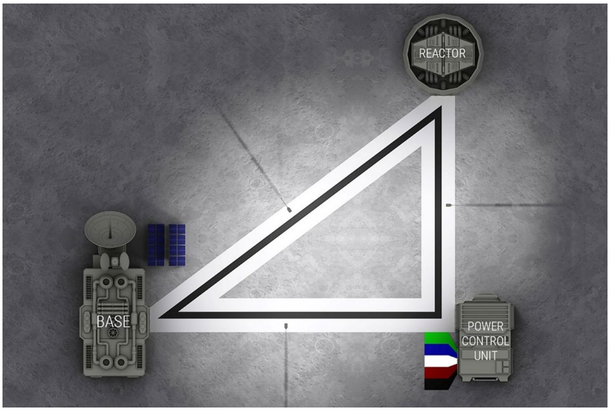

Fig. 3 Moon station working area

form any physical measurements using meters etc. on the working area. False trials were punished with 3 min of waiting to prevent entering random values.

- *Mission 2,* the second mission was entering the power control unit (Fig. 4). To prevent radiation leakage in the reactor, the reactor energy must be cut off. Therefore, it is necessary to enter the power unit. However, the door of the power control unit has a combination lock with five sliders. Each slider should be arranged according to the reflection rate of the light on its background colour. The students were expected to measure reflected light intensity on a coloured base using a colour sensor (it also measures the ambient and reflected light intensity) and they were asked to evaluate the reflection rate of each colour on the experiment interface of EV3 software. When they arranged the all-colour-sliders on the web page (Fig. 4 top left corner) according to the graph they had investigated, the door would open and they could accomplish the mission.
- *Mission 3,* after entering the power control unit, the astroneers would realize that a part of the power control unit was broken. The broken part was needed to be replaced with a new one. The spare part had been sent from the Earth in a capsule. The capsule fell to a random point on the lunar surface. Astroneers could find the capsule and design a robot to bring it to the base. A small box was used as a capsule and placed at a random point in the working area. Astroneers were firstly asked to design a robot that could detect the location of the capsule and then to carry the capsule to the base. The task would be completed when the code inside the capsule was entered on the website.
- *Mission 4,* the spare part sent from Earth was placed, but it did not work as intended. At the moon station, the doors were started to open and close automatically. The door of the power control unit was opened 10 s after the base's door was closed and stayed open for 10 s. The reactor's door was open for 20 s after the door of the power control unit was closed and stayed open for 10 s. 30 s after the reactor's door was closed, the base door was open. Astroneers needed to program their robots in such a way that it could reach the specified section when the doors were open. In this mission, it's expected that

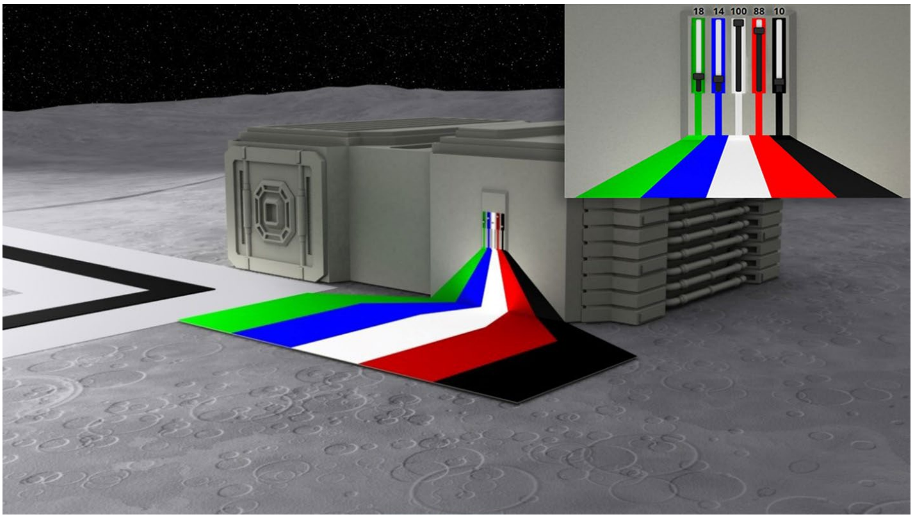

Fig. 4 Power control unit's colour lock and sliders on the website

the participants could use the lengths of each side of the area they measured in the first mission.

- *Mission 5,* the last mission was to measure the angles of the triangle. Astroneers, who performed all the tasks given, were asked to measure the specified corner angles using robots to check the distances between the base, the power control unit, and the reactor they measured earlier. First, using the colour sensor, they were asked to make a robot following the line on the moon station table and then to integrate a gyroscope sensor into the robot to examine the data from the gyroscope sensor to analyze the robot's turns and find the corner angles.

In the projects section, the students worked on their projects on the last days of the camps. They created projects to solve their daily life problems using their robotics sets. A Lego Mindstorms EV3 expansion set was distributed to each group to support their free design. Each group designed and programmed their robot according to their projects. For example, one group prepared an automatic bird feeder; the other group created a wearable robot for blind people, while another group designed a t-shirt folding robot. They experienced the problem, project, and design-based learning during the projects section. Each group presented their projects and robot performance to their parents, teachers, and friends on the last day of the camps.

Research design

This study used a pre-test post-test quasi-experimental design without a control group (Fraenkel et al., 2011). The significance of the difference between pre-test and post-test measurements of groups was tested in this research design (Büyüköztürk et al., 2017; Fraenkel et al., 2011). In this context, pre-test and post-test results were obtained for "STEM Attitude" and "STEM Perception", which are the dependent variables of the study.

Instruments

One of the data collection instruments of the study was the "STEM Perception Scale", which is a semantic survey that measures the students' interest in science, technology, engineering, mathematics, and STEM careers. The instrument includes five opposite adjective pairs for each sub-dimension. There are seven options between these two opposite poles. Each factor on the STEM perception scale has the same five items and is measured on a 7-point scale. The maximum score for each factor is 35, and the maximum total scale score is 175. The scale was developed by Knezek and Christensen (1998) and adopted to Turkish by Gülhan and Şahin (2016). They measured Cronbach's alpha reliability coefficient of the test as 0.89. Cronbach's alpha values of sub-dimensions of the test were between 0.70 and 0.89. Example questions from the scale are presented below.

To me, SCIENCE is:

1	Fascinating	1	2	3	4	5	6	7	Mundane
2	Appealing	1	2	3	4	5	6	7	Unappealing
3	Exciting	1	2	3	4	5	6	7	Unexciting

The STEM Attitude Scale, which is the other quantitative measurement tool, consists of four sub-dimensions which are mathematics (8 items), science (9 items), engineering-technology (9 items), and twenty-first-century skills (11 items). A 5-point Likert-type scale with 37 items was developed by Friday Institute for Educational Innovation (FIEI), (2012). Similar to the STEM perception test, Gülhan and Şahin (2016) have adapted the scale, and they reported that Cronbach's alpha reliability coefficients of sub-dimensions of the scale were between 0.78 and 0.90. The total Cronbach's alpha value of the scale was 0.92. The test ranged from 1 (strongly disagree) to 5 (strongly agree). Three items (1st, 3rd, 5th items) in the mathematics section and 16th item in the science section were reversed items. Some example questions from the mathematics section are presented below.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Math has been my worst subject	1	2	3	4	5
I would consider choosing a career that uses math	1	2	3	4	5
Math is hard for me	1	2	3	4	5

Data collection and analysis

STEM perception scales and STEM attitude scales were applied on the first days (before the robotics activities) and the last days (after the presentations) in both of the camps. Collected data were analyzed by using SPSS software. The normality assumption was violated in most of the sub-dimensions and total attitude and total perception scores of the pre- and post-tests of both camps. Therefore, The Wilcoxon's matched-pairs signed-ranks test, which is a nonparametric test for comparing the central tendency of two matched (related) samples, were used for statistical analysis (Howell, 2014). The Mann–Whitney U test was used to compare the first and second robotics camps' data. The Mann–Whitney U test is a nonparametric alternative to the t-test (Fraenkel et al., 2011).

Results

This section presents an overview of the students' responses to STEM perception and attitude scales. The findings were presented under Perception towards STEM and Attitude towards STEM in line with the research questions.

Perception towards STEM

Means and standard deviations of STEM perception test for both camps are presented in Table 1.

As seen in Table 1, when the pre-test and post-test scores of the two camps are analyzed in terms of STEM areas, the highest mean score is for Mathematics ($M_{\text{pre-17}}=30.50$; $M_{\text{post-17}}=32.50$; $M_{\text{pre-18}}=31.98$; $M_{\text{post-18}}=32.15$) and the

Table 1 Descriptives for STEM perception test

	RC-17				RC-18			
	Pre-test		Post-test		Pre-test		Post-test	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Science	30.40	4.90	31.35	4.31	29.51	4.00	29.20	4.23
Mathematics	30.50	5.17	32.50	4.25	31.98	4.57	32.15	3.88
Engineering	26.22	7.15	27.50	7.00	24.75	6.51	25.09	6.80
Technology	28.40	5.87	29.35	6.27	30.67	3.67	30.19	5.43
Career	30.04	5.40	31.25	5.21	29.05	4.30	28.43	5.61
Total	145.56	13.21	151.95	16.45	145.96	12.95	145.07	19.10

Table 2 Mann–Whitney U test of differences in STEM perception pre-tests between the camps

	U	p	r
Science	170.50	0.299	0.162
Mathematics	181.50	0.440	0.120
Engineering	187.50	0.546	0.098
Technology	171.00	0.305	0.160
Career	172.00	0.318	0.156
Total	205.50	0.906	0.018

Table 3 Wilcoxon's matched-pairs signed-ranks test of STEM perception test for the merged group

	Z	p
Post-science–Pre-science	− 0.521	0.603
Post-mathematics–Pre-mathematics	− 1.690	0.091
Post-engineering–Pre-engineering	− 0.690	0.490
Post-technology–Pre-technology	− 0.402	0.687
Post-career–Pre-career	− 0.319	0.749
Post-total–Pre-total	− 1.354	0.176

lowest mean score is for Engineering ($M_{\text{pre-17}}=26.22$; $M_{\text{post-17}}=27.50$; $M_{\text{pre-18}}=24.75$; $M_{\text{post-18}}=25.09$). The results of the Mann Whitney U (MWU) test that were used to compare the pre-test scores of both camps are shown in Table 2.

As shown in Table 2, when the pre-test scores of both camps were compared through the MWU test, no statistically significant difference between the perception test scores of the first and second camp participants was found. After the MWU test results, both camps' perception data were merged and Wilcoxon's matched-pairs signed-ranks test was conducted to answer the first research question.

Wilcoxon's matched-pairs signed-ranks test for the merged group resulted in no significant mean difference in students' perception toward STEM. Robotics camps have no effects on students' perceptions neither total perception nor any sub-dimensions of the

Table 4 Wilcoxon's matched-pairs signed-ranks test of STEM perception test for both camps

	RC-17		RC-18	
	Z	p	Z	p
Post-science–Pre-science	– 0.934	0.350	– 0.280	0.779
Post-mathematics–Pre-mathematics	– 1.960	0.050*	– 0.441	0.659
Post-engineering–Pre-engineering	– 0.883	0.377	– 0.261	0.794
Post-technology–Pre-technology	– 0.569	0.569	– 0.228	0.820
Post-career–Pre-career	– 1.086	0.278	– 0.664	0.507
Post-total–Pre-total	– 2.234	0.025*	– 0.187	0.852

*$p < .05$

Table 5 Descriptives for STEM attitude test

	RC-17				RC-18			
	Pre-test		Post-test		Pre-test		Post-test	
	M	SD	M	SD	M	SD	M	SD
Mathematics	32.21	8.57	35.60	4.51	31.91	5.36	31.17	6.35
Science	33.63	6.70	32.65	6.82	32.40	6.28	34.09	6.25
Engineering-Technology	32.30	6.35	32.40	6.30	34.25	6.51	35.25	6.29
twenty-first-century skills	43.12	10.23	45.25	6.25	44.50	9.23	43.66	9.10
Total	141.25	25.23	148.90	16.52	143.06	23.04	144.1	23.27

STEM Perception Test which are science, technology, engineering, mathematics, and career (See Table 3).

When both camps were analyzed individually on STEM perception change, according to Wilcoxon's matched-pairs signed-ranks test result, only the difference at mathematics sub-dimension was statistically significant ($Z_{Math} = -1.960$, $p = 0.05$). The other sub-dimensions' mean differences were not statistically significant. As shown in Table 4, the Wilcoxon's matched-pairs signed-ranks test comparing first robotics campers' overall perception scores before and after the robotics camp showed that there was a significant increase in perceptions towards STEM ($Z_{Total} = -2.234$, $p = 0.025$). However, Wilcoxon's matched-pairs signed-ranks for pre and post perception scores of the students attending the second camp showed that the second robotics camp did not elicit a statistically significant change in participants' perception towards STEM.

Attitude towards STEM

Table 5 presents means and standard deviations of scores measured by STEM attitude test from both camps.

As shown in Table 5, twenty-first-century skills have the highest score ($M_{21cs} = 43.12$) and mathematics has the lowest score ($M_{Math} = 32.21$) at pre-test of the students who attended the first camp. Similarly, twenty-first-century skills were the highest

Table 6 Mann–Whitney U test of differences in STEM attitude pre-tests between both camps

	U	p	r
Mathematics	155.00	0.324	0.158
Science	165.50	0.490	0.111
Engineering-Technology	163.00	0.447	0.122
twenty-first-century skills	174.50	0.663	0.070
Total	189.00	0.978	0.004

($M_{21cs}=44.50$) and mathematics was the lowest ($M_{Math}=31.91$) scores for the second camp pre-test scores. The MWU test was used to compare the pre-test scores of both camps.

As shown in Table 6, similar to STEM perception test analysis, Mann–Whitney U test of STEM attitude pre-test scores showed no significant differences between the first and the second camp participants' attitudes towards STEM at the beginning of the camps. Therefore, these two camps' data were merged for further analysis.

Wilcoxon matched-pairs signed-rank tests were conducted on merged data set to determine whether there was a difference in the STEM attitude scores of the students. There wasn't any significant change in the total students' attitudes scores. The only meaningful change was observed at the science sub-dimension ($Z_{Science}=-2.359$, $p=0.018$).

Similarly, Wilcoxon matched-pairs signed-rank tests were conducted individually for each camp to evaluate whether there was a difference in the STEM attitude scores. Similar to the merged data set, the results showed no statistically significant increase in the science sub-dimension of the attitude scales for the students attending the second

Table 7 Wilcoxon's matched-pairs signed-ranks test of STEM attitude test for the merged group

	Z	p
Post-mathematics–Pre-mathematics	− 1.089	0.276
Post-science–Pre-science	− 2.359	0.018*
Post-eng.-technology–Pre-eng.-technology	− 0.523	0.601
Post-twenty-first-century skills–Pre-twenty-first-century skills	− 0.451	0.652
Post-total–Pre-total	− 1.207	0.227

*$p<.05$

Table 8 Wilcoxon's matched-pairs signed-ranks test of STEM attitude test for both camps

	RC-17		RC-18	
	Z	p	Z	p
Post-mathematics–Pre-mathematics	− 1.685	0.092	− 0.282	0.778
Post-science–Pre-science	− 1.458	0.145	− 1.966	0.049*
Post-eng.-technology–Pre-eng.-technology	− 0.181	0.856	− 1.337	0.181
Post-twenty-first-century skills–Pre-twenty-first-century skills	− 1.233	0.217	− 0.720	0.472
Post-total–Pre-total	− 1.087	0.277	− 0.632	0.527

*$p<.05$

camp ($Z_{Science} = -1.966$, $p = 0.049$). There was no significant difference in the other sub-dimensions (mathematics, engineering-technology, and twenty-first-century skills) of the attitude scale either. The analysis resulted that there was no significant difference in students' overall attitudes towards STEM. Neither robotics camp affected students' attitudes towards STEM (see Tables 7, 8).

Discussion and conclusion

In this study, the effects of STEM-focused robotics activities on perception and attitudes towards STEM were analyzed. The effects of STEM-focused robotics camps on secondary school students' perceptions and attitudes towards STEM were examined through a pre-test post-test quasi-experimental design without a control group. The findings from the two camps showed that the highest perception among STEM sub-dimensions is towards Mathematics and the lowest perception is towards Engineering. The perceptions of secondary school students towards STEM sub-dimensions also differ in the literature. In some studies, contrary to this study, the lowest perception was determined as Mathematics (Christensen et al., 2015; Knezek et al., 2013; Larkins et al., 2013). Gülhan and Şahin (2016) stated that among all the sub-dimensions of the perception scale, the lowest measured score was engineering similar to the findings of this study. According to the findings obtained by Conrad et al. (2018), the lowest perception was science and the highest perception was engineering. All these findings emphasize that perceptions of STEM sub-dimensions might be quite different.

The overall result of this study showed that STEM-related robotics camp has a non-significant effect on students' perceptions toward STEM. Few studies investigated the effect of STEM-focused robotics camps. In one of these studies, Larkins et al. (2013), determined that the STEM-focused robot camp positively affected the STEM perceptions of middle school students. Conrad et al. (2018) conducted a week long robotics summer camp, and they measured an increase in STEM perception between pre-and post-camps results. Similar to this study, gains from the robotics camp were not statistically significant. A non-significant increase in perception could be attributed to the short 8–10 days duration of the robotics camps and the small sample size of the study. The instrument could not have enough sensitivity to reflect the change in highly enthusiastic participants' perceptions (Conrad et al., 2018).

Despite that, the non-significant result of RC-18, students' perception toward STEM was statistically significant at total perception scores and mathematics sub-dimension in RC-17. Results of the RC-18 aligned with related literature of Chen and Chang (2018) and Roberts et al. (2018). The students' engagement on the authentic problems about the moon station and their project in the last section of the camp could be the reason for the positive change in STEM perception. However, the second camp (RC18) was also realized with the same structure, process, and content and had no significant impact on perception towards STEM, which does not coincide with the positive findings of the studies in the literature and the first camp (RC17) in our study. The only difference between the two camps was the participants. Participants of RC-17 were mostly from the students who attended the Science and Art Center of the Ministry of Education. Only high-achiever students are accepted to Science and Art Center by exam. RC-18 was conducted at a boarding school. Although both camp students have similar perceptions and attitude levels toward STEM at the beginning, their academic performance or any other character traits could be the reason for the difference between the two camps. Further studies could present and identify the causing variable.

Regarding the findings of the attitude towards STEM, another dependent variable discussed in the study, no significant change in students' attitudes towards STEM was found after STEM-focused robotics activities. This situation can be interpreted as that the ten-day STEM-focused robotics activities carried out within the study do not change attitudes or there is no significant increase because of the high attitude level determined in the pre-test. In their research with secondary school students, Kaloti-Hallak et al., (2015) stated that contrary to the decrease in the control group, the students in the experimental group maintained their pre-test attitude levels in the post-test and this was a positive indicator. In fact, this finding is similar to most of the studies examining the effects of STEM-focused robotic applications on attitude towards STEM in the literature. In these experimental studies that were conducted during different application periods, it no significant change was observed in the attitudes of the participants towards STEM (Ching et al., 2019; Conrad et al., 2018; Holmquist, 2014; Leonard et al., 2016b; Nugent et al., 2016).

The result of the non-significant attitude change can be explained by the fact that it requires much more time, effort, and determination since this change does not occur quickly (Pickens, 2005). Nevertheless, attitudes towards STEM showed an increase in both camps although it was not significant. This is due to increases or decreases in different sub-dimensions in the two camps. Among these dimensions, science was seen as the only sub-dimension that was statistically significant although it was very close to the *P*-value (0.05). Leonard et al. (2016b) also determined that there was only an increase in science among STEM sub-dimensions in the research conducted with secondary school students. Even though the robotic tasks carried out in the research are based on mathematics and engineering design, the increase in the science dimension draws an attention to the interdisciplinary structure and interaction of STEM sub-dimensions in line with the aim of STEM education, which is to give individuals an interdisciplinary perspective on problems, knowledge, and skills. The students attending STEM activities realize that STEM is directly related to life and different sub-dimensions of STEM can be used together when applying their knowledge to the real-world problems and challenges.

Further researches are recommended to evaluate the relationship between robotics activities and STEM perceptions and attitudes. Since the STEM perceptions and attitudes of the participants in this research were above the average before the implementation, the effect of STEM-focused robotics activities was limited. Therefore, it may be more appropriate to work with students with low STEM perception and attitude levels in the researches. Moreover, the study resulted that short-term robotic camps have non-significant or little effects on middle school students' attitudes and perceptions. The duration of the robotic camps is thought to have an effect especially on attitude change. Therefore, further studies should consider a longer duration of robotic camps to examine the impact on STEM attitudes and perception. Also, it is seen that the participants of the current related studies were mostly selected from secondary school students. For this reason, working with participants from different school levels in the research will enable both the expansion and comparison of the findings in the literature.

References

Ajzen, I. (2005). *Attitudes, personality, and behavior*. . McGraw-Hill Education.
Alimisis, D. (2013). Educational robotics: Open questions and new challenges. *Themes in Science and Technology Education, 6*(1), 63–71.
Alimisis, D., & Kynigos, C. (2009). Constructionism and Robotics in education. In Alimisis, D (Ed.) *Teacher education on robotics-enhanced constructivist pedagogical methods* (pp. 11–26). Retrieved from http://dide.ilei.sch.gr/keplinet/education/docs/book_TeacherEducationOnRobotics-ASPETE.pdf
Bazzett, T. J., Zahid, Z., & Brady, M. A. (2018). Engaging, entertaining, and educating under-served and at-risk youth with STEM-based activities. *Journal of Undergraduate Neuroscience Education, 17*(1), A89–A96.
Beers, S. Z. (2011). What are the skills students will need in the 21 st century? 1–6. Retrieved from https://cosee.umaine.edu/files/coseeos/21st_century_skills.pdf
Benitti, F. B. V. (2012). Exploring the educational potential of robotics in schools: A systematic review. *Computers and Education, 58*(3), 978–988. https://doi.org/10.1016/j.compedu.2011.10.006.
Benitti, F. B. V., & Spolaôr, N. (2017). How have robots supported STEM teaching? In M. S. Khine (Ed.), *Robotics in STEM education: Redesigning the learning experience*. (pp. 103–129). Springer International Publishing. https://doi.org/10.1007/978-3-319-57786-9_5.
Binns, I. C., Polly, D., Conrad, J., & Algozzine, B. (2016). Student perceptions of a summer ventures in science and mathematics camp experience. *School Science and Mathematics, 116*(8), 420–429. https://doi.org/10.1111/ssm.12196.
Büyüköztürk, Ş, Kılıç Çakmak, E., Akgün, Ö. E., Karadeniz, Ş, & Demirel, F. (2017). *Bilimsel Araştırma Yöntemleri*. (22nd ed.). Pegem. https://doi.org/10.14527/9789944919289.
Bybee, R. W. (2010a). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher, 70*(1), 30–35.
Bybee, R. W. (2010b). What is STEM education? *Science, 329*(5995), 996–996. https://doi.org/10.1126/science.1194998.
Bybee, R. W. (2013). The case for STEM education: Challenges and opportunities. *NSTA Press*. https://doi.org/10.2505/9781936959259.
Castro, E., Cecchi, F., Salvini, P., Valente, M., Buselli, E., Menichetti, L., & Dario, P. (2018). Design and impact of a teacher training course, and attitude change concerning educational robotics. *International Journal of Social Robotics, 10*(5), 669–685. https://doi.org/10.1007/s12369-018-0475-6.
Chalmers, C. (2018). Robotics and computational thinking in primary school. *International Journal of Child-Computer Interaction, 17*, 93–100. https://doi.org/10.1016/j.ijcci.2018.06.005.
Chen, Y., & Chang, C. C. (2018). The impact of an integrated robotics STEM course with a sailboat topic on high school students' perceptions of integrative STEM, interest, and career orientation. *EURASIA Journal of Mathematics, Science and Technology Education, 14*(12), 1614–1633. https://doi.org/10.29333/ejmste/94314.
Chen, G., Shen, J., Barth-Cohen, L., Jiang, S., Huang, X., & Eltoukhy, M. (2017). Assessing elementary students' computational thinking in everyday reasoning and robotics programming. *Computers & Education, 109*, 162–175. https://doi.org/10.1016/j.compedu.2017.03.001.
Ching, Y. H., Yang, D., Wang, S., Baek, Y., Swanson, S., & Chittoori, B. (2019). Elementary school student development of STEM attitudes and perceived learning in a STEM integrated robotics curriculum. *TechTrends, 63*(5), 590–601. https://doi.org/10.1007/s11528-019-00388-0.
Christensen, R., Knezek, G., & Tyler-Wood, T. (2015). Alignment of hands-on STEM engagement activities with positive STEM dispositions in secondary school students. *Journal of Science Education and Technology, 24*(6), 898–909. https://doi.org/10.1007/s10956-015-9572-6.
Chung, C. J. C., Cartwright, C., & Cole, M. (2014). Assessing the impact of an autonomous robotics Competition for STEM education. *Journal of STEM Education: Innovations and Research, 15*(2), 24.
Conrad, J., Polly, D., Binns, I., & Algozzine, B. (2018). Student perceptions of a summer robotics camp experience. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 91*(3), 131–139. https://doi.org/10.1080/00098655.2018.1436819.
Corlu, M. S., Capraro, R. M., & Capraro, M. M. (2014). Introducing STEM education : Implications for educating our teachers for the age of innovation. *Education & Science, 39*(171), 74–85.
Ding, F., Cai, M., & Chen, S. (2019). Application of STEAM Theory in Robot Teaching. In *Proceedings of the 3rd international conference on economics and management, education, humanities and social sciences-EMEHSS 2019* (pp. 109–113). https://doi.org/10.2991/emehss-19.2019.24
Eguchi, A. (2014). Educational robotics for promoting 21st century skills. *Journal of Automation Mobile Robotics and Intelligent Systems, 8*(1), 5–11. https://doi.org/10.14313/jamris_1-2014/1.

Eguchi, A. (2015). Educational robotics as a learning tool for promoting rich environments for active learning (REALs). *Handbook of Research on Educational Technology Integration and Active Learning. IGI Global, PA* (pp. 19–47). https://doi.org/10.4018/978-1-4666-8363-1.ch002

Eguchi, A. (2016). RoboCupJunior for promoting STEM education, 21st century skills, and technological advancement through robotics competition. *Robotics and Autonomous Systems, 75*, 692–699. https://doi.org/10.1016/j.robot.2015.05.013.

Eguchi, A. (2017). Bringing robotics in classrooms. In M. S. Khine (Ed.), *Robotics in STEM education.* (pp. 3–31). Springer International Publishing. https://doi.org/10.1007/978-3-319-57786-9_1.

Fraenkel, J., Wallen, N., & Hyun, H. (2011). *How to Design and evaluate research in education*. (8th ed.). McGraw-Hill Education.

Friday Institute for Educational Innovation (2012). Student Attitudes toward STEM: Survey-upper Elementary School Students, Raleigh, NC: Author

Gazibeyoglu, T., & Aydin, A. (2019). The effect of STEM-based activities on 7th grade students' academic achievement in force and energy unit and students' opinions about these activities. *Universal Journal of Educational Research, 7*(5), 1275–1285. https://doi.org/10.13189/ujer.2019.070513.

Garber, G. (2013). *Instant LEGO Mindstorm EV 3.* Packt Publishing. Retrieved from https://www.scribd.com/book/253053736/Instant-LEGO-Mindstorm-EV3

Gura, M. (2012). Lego robotics: STEM sport of the mind. *Learning & Leading with Technology, 40*(1), 12–16.

Guzey, S. S., Harwell, M., & Moore, T. (2014). Development of an instrument to assess attitudes toward science, technology, engineering, and mathematics (STEM). *School Science and Mathematics, 114*(6), 271–279. https://doi.org/10.1111/ssm.12077.

Gülhan, F., & Şahin, F. (2016). The effects of science-technology-engineering-math (STEM) integration on 5th grade students' perceptions and attitudes towards these areas. *International Journal of Human Sciences, 13*(1), 602. https://doi.org/10.14687/ijhs.v13i1.3447.

Hallström, J., & Schönborn, K. J. (2019). Models and modelling for authentic STEM education: Reinforcing the argument. *International Journal of STEM Education*. https://doi.org/10.1186/s40594-019-0178-z.

Holmquist, S. K. (2014). *A Multi-Case Study of Student Interactions with Educational Robots and Impact on Science, Technology, Engineering, and Math (STEM) Learning and Attitudes*. University of South Florida. Retrieved from https://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=6239&context=etd

Howell, D. C. (2014). *Fundamental Statistics for the Behavioral Sciences*. Belmont, Calif.: Wadsworth, Cengage Learning. Retrieved from https://www.uvm.edu/~statdhtx/fundamentals8/index.html

Ioannou, A., & Makridou, E. (2018). Exploring the potentials of educational robotics in the development of computational thinking: A summary of current research and practical proposal for future work. *Education and Information Technologies, 23*(6), 2531–2544. https://doi.org/10.1007/s10639-018-9729-z.

Jim, C. K. W. (2010). *Teaching with LEGO Mindstorms Robots: Effects on Learning Environment and Attitudes toward Science*. *ProQuest Dissertations and Theses*. The University of Texas at Dallas, United States, Texas. Retrieved from https://search.proquest.com/docview/851128461

Kafai, Y. (Ed.), Resnick, M. (Ed.). (1996). *Constructionism in Practice: Designing, Thinking, and Learning in a Digital World*. New York: Routledge. https://doi.org/10.4324/9780203053492

Kaloti-Hallak, F., Armoni, M., & Ben-Ari, M. (2015). Students' attitudes and motivation during robotics activities. In *Proceedings of the Workshop in Primary and Secondary Computing Education* (pp. 102–110). https://doi.org/10.1145/2818314.2818317

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*. https://doi.org/10.1186/s40594-016-0046-z.

Khanlari, A. (2013). Effects of educational robots on learning STEM and on students' attitude toward STEM. In Proceedings of *5th international conference on engineering education: aligning engineering education with industrial needs for nation development, ICEED 2013*, (pp. 62–66). https://doi.org/10.1109/iceed.2013.6908304

Kim, C., Kim, D., Yuan, J., Hill, R. B., Doshi, P., & Thai, C. N. (2015). Robotics to promote elementary education pre-service teachers' STEM engagement, learning, and teaching. *Computers & Education, 91*, 14–31. https://doi.org/10.1016/j.compedu.2015.08.005.

Knezek, G., Christensen, R., Tyler-Wood, T., & Periathiruvadi, S. (2013). Impact of environmental power monitoring activities on middle school student perceptions of STEM. *Science Education International, 24*(1), 98–123.

Knezek, G., & Christensen, R. (1998). Internal consistency reliability for the teachers' attitudes toward information technology (TAT) questionnaire. In *Proceedings of the society for information technology in teacher education annual conference* (pp. 831–836).

Kucuk, S., & Sisman, B. (2017). Behavioral patterns of elementary students and teachers in one-to-one robotics instruction. *Computers & Education, 111*, 31–43. https://doi.org/10.1016/j.compedu.2017.04.002.

Larkins, D. B., Moore, J. C., Rubbo, L. J., & Covington, L. R. (2013). Application of the Cognitive Apprenticeship Framework to a Middle School Robotics Camp. In *Proceeding of the 44th ACM technical symposium on computer science education-SIGCSE13* (pp. 89–94). ACM. https://doi.org/10.1145/2445196.2445226

Leonard, J., Buss, A., Gamboa, R., Mitchell, M., Fashola, O. S., Hubert, T., & Almughyirah, S. (2016a). Using robotics and game design to enhance children's self-efficacy, STEM attitudes, and computational thinking skills. *Journal of Science Education and Technology, 25*(6), 860–876. https://doi.org/10.1007/s10956-016-9628-2.

Leonard, J., Buss, A., Unertl, A., & Mitchell, M. (2016b). Using robotics and game design to promote pathways to STEM. *North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 1487–1494). Retrieved from https://files.eric.ed.gov/fulltext/ED583748.pdf

Lin, K. Y., Hsiao, H. S., Williams, P. J., & Chen, Y. H. (2020). Effects of 6E-oriented STEM practical activities in cultivating middle school students' attitudes toward technology and technological inquiry ability. *Research in Science & Technological Education, 38*(1), 1–18. https://doi.org/10.1080/02635143.2018.1561432.

Li, Y., Huang, Z., Jiang, M., & Chang, T. W. (2016). The effect on pupils' science performance and problem-solving ability through lego: An engineering design-based modeling approach. *Journal of Educational Technology & Society, 19*(3), 143–156.

Maio, G. R., & Haddock, G. (2004). Theories of attitude: Creating a witches' brew. In *Contemporary perspectives on the psychology of attitudes* (pp. 443–471). Psychology Press. https://doi.org/10.4135/9781446214299

Maio, G. R., Haddock, G., & Verplanken, B. (2018). The psychology of attitudes and attitude change. *Sage Publications Limited*. https://doi.org/10.4135/9781446214299.

Malec, J. (2001). Some thoughts on robotics for education. In *2001 AAAI spring symposium on robotics and education*. Retrieved from http://fileadmin.cs.lth.se/cs/Personal/Jacek_Malec/psfiles/aaai01rae.pdf

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education, 95*(5), 877–907. https://doi.org/10.1002/sce.20441.

Mataric, M. J., Koenig, N. P., & Feil-Seifer, D. (2007). Materials for enabling hands-on robotics and STEM education. In *AAAI Spring symposium: Semantic scientific knowledge integration* (pp. 99–102). Retrieved from https://www.aaai.org/Papers/Symposia/Spring/2007/SS-07-09/SS07-09-022.pdf

Maxwell, J. W. (2006). Re-situating constructionism. *The International Handbook of Virtual Learning Environments*. https://doi.org/10.1007/978-1-4020-3803-7_11.

Milli Eğitim Bakanlığı (MEB), (2016). Bilim ve Sanat Merkezleri Yönergesi. Retrieved from https://orgm.meb.gov.tr/meb_iys_dosyalar/2016_10/07031350_bilsem_yonergesi.pdf

Moore, T. J. (2008). STEM integration: Crossing disciplinary borders to promote learning and engagement. *Invited Presentation to the Faculty and Graduate Students of the UTeachEngineering, UTeachNatural Sciences, and STEM Education Program Area at University of Texas at Austin*, 1–13.

Myers, D. G., & DeWall, C. N. (2018). *Psychology (12th Ed.)*. Macmillan Learning. Retrieved from https://books.google.com.tr/books?id=16iIswEACAAJ

National Education Association. (2012). *Preparing 21st century students for a global society: An educator's guide to the "Four Cs."* . National Education Association.

National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. . National Academies Press.

Nemiro, J., Larriva, C., & Jawaharlal, M. (2017). Developing Creative behavior in elementary school students with robotics. *The Journal of Creative Behavior, 51*(1), 70–90. https://doi.org/10.1002/jocb.87.

Nugent, G., Barker, B., Grandgenett, N., & Welch, G. (2016). Robotics camps, clubs, and competitions: Results from a US robotics project. *Robotics and Autonomous Systems, 75*, 686–691. https://doi.org/10.1016/j.robot.2015.07.011.

Ortiz, A. M., Bos, B., & Smith, S. (2015). The power of educational robotics as an integrated STEM learning experience in teacher preparation programs. *Journal of College Science Teaching, 44*(5), 42–47. https://doi.org/10.2505/4/jcst15_044_05_42.

Páez, T. M., Aguilera, D., Javier, F., & Palacios, P. (2019). What are we talking about when we talk about STEM education ? A review of literature. *Science Education, 103*(4), 799–822. https://doi.org/10.1002/sce.21522.

Papert, S. (1993). *Mindstorms: Children, computers, and powerful ideas*. Basic Books.

Partnership for 21st Century Skills (P21). (2009). *Framework for 21st Century Learning* P21 Tucson, AZ. Retrieved from http://www.p21.org/storage/documents/docs/P21_framework_0816.pdf. Accessed 20 Sept 2018.

Pickens, J. (2005). Attitudes and Perceptions. *Organizational Behavior in Health Care*, 43–76.

Reich-Stiebert, N., Eyssel, F., & Hohnemann, C. (2019). Involve the User! changing attitudes toward robots by user participation in a robot prototyping process. *Computers in Human Behavior, 91*, 290–296. https://doi.org/10.1016/j.chb.2018.09.041.

Roberts, T., Jackson, C., Mohr-Schroeder, M. J., Bush, S. B., Maiorca, C., Cavalcanti, M., & Cremeans, C. (2018). Students' perceptions of STEM learning after participating in a summer informal learning experience. *International Journal of STEM Education, 5*(1), 1–14. https://doi.org/10.1186/s40594-018-0133-4.

Sahin, A., Ayar, M. C., & Adiguzel, T. (2013). STEM related after-school program activities and associated outcomes on student learning. *Educational Sciences: Theory & Practice, 14*(1), 309–323. https://doi.org/10.12738/estp.2014.1.1876.

Sansing, C. (2014). *A highly intelligent brick*. . Media Source Inc.

Scott, C. E. (2009). *A Comparative Case Study of the Characteristics of Science, Technology, Engineering, and Mathematics (STEM) Focused High Schools*. (M. Hjalmarson, Ed.), *Development*. George Mason University, Virginia, United States.

Sherrod, S. E., Dwyer, J., & Narayan, R. (2009). Developing science and math integrated activities for middle school students. *International Journal of Mathematical Education in Science and Technology, 40*(2), 247–257.

Simonson, M. R., & Maushak, N. (1996). Situated learning, instructional technology, and attitude change. *Situated Learning Perspectives*, 225–242.

Takacs, A., Eigner, G., Kovács, L., Rudas, I. J., & Haidegger, T. (2016). Teacher's Kit: Development, Usability, and Communities of Modular Robotic Kits for Classroom Education. In Proceedings of *IEEE Robotics & Automation Magazine, 23*, (pp. 30–39). https://doi.org/10.1109/mra.2016.2548754

Tanenbaum, C. (2016). *STEM 2026: A vision for innovation in STEM education*. . US Department of Education.

Tang, K., & Williams, P. J. (2019). STEM literacy or literacies? Examining the empirical basis of these constructs. *Review of Education, 7*(3), 675–697. https://doi.org/10.1002/rev3.3162.

Taylor, K., & Baek, Y. (2019). Grouping Matters in computational robotic activities. *Computers in Human Behavior, 93*, 99–105. https://doi.org/10.1016/j.chb.2018.12.010.

Thibaut, L., Knipprath, H., Dehaene, W., & Depaepe, F. (2018). The influence of teachers' attitudes and school context on instructional practices in integrated STEM education. *Teaching and Teacher Education, 71*, 190–205. https://doi.org/10.1016/j.tate.2017.12.014.

Tsupros, N., Kohler, R., & Hallinen, J. (2009). *STEM education: A project to identify the missing components, Intermediate Unit 1 and Carnegie Mellon*. . Pennsylvania.

Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM). *Journal of Psychoeducational Assessment, 33*(7), 622–639. https://doi.org/10.1177/0734282915571160.

Vennix, J., den Brok, P., & Taconis, R. (2018). Do outreach activities in secondary STEM education motivate students and improve their attitudes towards STEM? *International Journal of Science Education, 40*(11), 1263–1283. https://doi.org/10.1080/09500693.2018.1473659.

Wiebe, E., Unfried, A., & Faber, M. (2018). The Relationship of STEM attitudes and career interest. *Eurasia Journal of Mathematics, Science and Technology Education*. https://doi.org/10.29333/ejmste/92286.

Zimbardo, P. G., & Leippe, M. R. (1991). *The psychology of attitude change and social influence*. . Mcgraw-Hill Book Company.

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