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Research Article

Effects of a summer robotics camp on students' STEM career interest and knowledge structure

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The present study focuses on the assessment of summer robotics camp designed for 7th grade students who were supposed to work on a STEM-related problem through modeling and design activities. It was exclusively investigated the effects of these activities on the STEM-related career interests and knowledge structures of students. The students were expected to develop basic robotics and design skills in the camp, and to use them in project design in the context of problem solving processes. The camp activities were designed in the alignment of P3 Task Taxonomy. A mixed design method was adapted in this study as it focused both on the effects of an experimental intervention and identification of the students' conceptual constructs. Accordingly, simultaneous and sequential data collection techniques were used to provide satisfactory responses to the research questions. The results showed that the students the students' career interest in engineering increased more significantly than the other STEM fields. Furthermore, word association tests that were applied before and after the camp, in order to assess the change in the students' knowledge structures with the keywords Coding, Design, Problem, Modeling, Space, and Robot showed that the number of terms associated with these keywords were increased. In a nutshell, the education activity provided in the context of this study reinforced the students' career interests in engineering in particular, and facilitated the development of their knowledge structures, and ability to define associations between terms.

Keywords: STEM education; Robotics; STEM career interest; Knowledge structure; P3 task taxonomy

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1. Introduction

The ever increasing pace of industrial and technological development around the globe, as well as an increased emphasis on defense requirements led the countries to implement reforms of their education policies. It is now widely accepted that engineering education, in particular, should begin as early as primary and secondary schools. In consequence, STEM (Science, Technology, Engineering and Mathematics) education, which provides a combination with engineering, mathematics, science, and technology, has gradually become more popular. In parallel to the American Next Generation Science Standards [NGSS] (2013), great significance attached to STEM education with a particular focus on science and engineering practices in primary and secondary

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Science curricula in Turkey (Ministry of National Education [MoNE], 2018). These efforts aim at improving the students' STEM skills with a view to coping better with the challenges imposed by globalization as well as the knowledge-based economy (Luo et al., 2019). In this context, various education programs related to STEM were designed with the aim of developing K-12 students' knowledge, skills and motivation with respect to STEM (Stubbs et al., 2014).

The disciplinary nature of the curricula causes certain difficulties such as lack of teacher collaboration in implementing interdisciplinary approaches at schools (Nadelson & Seifert, 2017). To overcome these challenges, an integrated STEM curriculum is proposed as a potential solution by enabling students to generate solutions to real life problems through an interdisciplinary lens (Furner & Kumar, 2007). Based on a systematic review of STEM education programs, Thibaut et al. (2018) proposed a theoretical framework for integrated STEM education practices. The framework in concern refers to five distinct pillars of integrated STEM education that is grounded on the social constructivism: integration of STEM content, problem-centered learning, inquiry-based learning, design-based learning and cooperative learning. Accordingly, it is widely accepted that the environments where knowledge is actively structured by the students, multiple disciplines are integrated, real life problems are considered as starting points, inquiries are involved in the process, and learning is realized based on cooperation rather than personal experience are effective in STEM education.

The integration of Engineering Design Process and STEM enables students to relate science and mathematics concepts in real-life contexts through technological tools (Sen et al., 2021). One of the ways to integrate Engineering Design Process and STEM is through educational robotics applications. Educational robotics offers students in K-12 physical manipulatives, where they can test variables during the engineering design process in engineering education. In addition, it provides the students with the opportunity to use programming language elements that allow them to receive immediate feedback (Ortiz et al., 2015). Robotics encourages students to work in cooperation by making them familiar with the interdisciplinary nature of STEM as well as providing them insights into the STEM-related concepts (Yuen et al., 2014). Besides, robotics is an effective field of practice in terms of developing the students' engineering design skills, and facilitating their engineering activities (Kopcha et al., 2017). Furthermore, Robotics education can be viewed as a form of engineering education that help them develop both hands-on and cognitive skills (Zhong et al., 2020). Despite the positive effects of STEM education on students, it was found that students avoided STEM-related courses in the formal school program and displayed less interest in these courses (Sha et al., 2015). At this point, it has been determined that STEM summer camps, one of the out-of-school learning environments that encourage students' voluntary participation, can increase their interest in STEM and their conceptual development about STEM (Davis & Hardin, 2013; Nugent et al., 2016).

One of the greatest sources of motivation for the proliferation of the STEM education in schools is to guide the students' interest in a career in STEM fields. Despite the growing need around the world, it is reported that the demand for the STEM-intensive business opportunities is decreasing (Kier et al., 2014). Children grow in an environment characterized by technology, and are often considered capable consumers of tech. On the other hand, their relationship with technology is not so simple to draw their interests to science, mathematics and engineering in the future. Therefore, it is important to examine the potential effect of the robotics-aided STEM education on the development of the students' STEM career interest.

When a robotics curriculum is designed to include problem-solving-based STEM activities, it can be of broader interest to students (Benitti, 2012). In such applications, an important element of problem solving is the storage and organization of information in the long-term memory (Kim & Tawfik, 2021). The organization of key concepts stored in the long-term memory is represented by knowledge structures (Clariana, 2010). With educational robotics applications, learners construct their knowledge structures through robot design and programming and represent their understanding through products they construct in the real world (Ching et al., 2019). In this respect, problem-solving STEM activities using educational robotics are likely to create a change in the knowledge structures of the learners.

The present study focuses on the assessment of a summer camp named Robotic Modeling: The Mars Mission STEM Learning Program (STEM-LEAP) designed for 7th grade students in Turkey, whereby the students are encouraged/supposed to work on a problem related to STEM disciplines through modeling and design activities. The study ultimately explored whether and how the implemented program changed the students' career interest and knowledge structures in STEM fields.

2. Theoretical Framework

2.1. Students' STEM Career Interest

The existing literature reveals that the students decide on their careers in the middle school (Tai et al., 2006) and that their interest in a career in STEM starts to grow in those years (Kier et al., 2014). Many organizations are developing STEM-based programs to attract more students to STEM fields and to prepare them for the increasing technological demands of the twenty-first century better. Studies have shown that increasing students' interest, achievements and positive attitudes towards STEM through STEM education programs will increase the number of students who choose to pursue a STEM-related career (Lavonen et al., 2008; Prokop et al., 2007). In this context, beyond routine school curricula, there are numerous out-of-school activities that have the potential to improve their interest in STEM, ranging from science-related hobbies to after-school programs, summer camps or STEM-related competitions. Participation in out-of-school science activities was found to have a strong positive relationship with a career choice related to STEM (Dabney et al., 2012). In that regard, the STEM-LEAP, which constitutes the focus of this study, was designed as a summer camp.

There are some studies focusing on the impacts of the summer camps as an out-of-school activity on students' STEM career interest, perceptions or choice. Dave et al. (2010) found that a STEM summer camp focused on the use of technology and aimed at promoting different engineering areas (electrical, mechanical and plastic) in applied laboratory-based modules improved campers' awareness of STEM careers. The participants who were already interested in engineering reported that they discovered different types of engineering thanks to camping. In addition, Hammack et al. (2015) found that attending a week-long engineering summer camp positively affected the attitudes of middle school students towards engineering and technology. Similarly, Yan et al. (2020) examined the students of a summer camp that included fun activities for transportation engineering, which was carried out to increase the interest and motivation of African-American high school students in engineering fields. At the end of the camp, it was found that the students who attended the camp were found significantly more likely to be interested in engineering and to choose engineering as a career in the future (Yan et al., 2020). In one of the few studies examining the impact of robotics practices on career interest in summer camp, Ayar et al. (2013) explored the experiences and career interests of 27 high school students who attended a two-week robotic summer camp. During the camp, the attendants experienced designing, building, testing and developing their robots, respectively. The study's results showed that the camp increased students' interest in engineering and helped them identify the engineering areas they wanted to study in their academic careers. In another study with a similar focus, a university-based summer robotics camp increased students' interest in engineering, computer science, and selected areas of basic and applied science (e.g., physics, chemistry, and energy) from STEM career fields, and significant differences were observed between male and female students (Conrad et al., 2018).

Another common observation is the underrepresentation of women in STEM-related fields (Wyss et al., 2012). Especially since engineering is seen as a male-specific occupation (Dave et al., 2010), the rate of women working in STEM-related jobs is not sufficient. This makes it valuable to investigate how this interest changes according to gender in studies focusing on students' STEM career interest.

2.2. Development of Students' Knowledge Structure

The constructivist theory argues that existing knowledge the learners may have regulates their perception of the world surrounding them, with new information are actively structured in the recipient's mind. To be able to identify the existing knowledge the students have in a given field, one should start with uncovering their existing knowledge structures. Existing knowledge plays a major part in constructing new knowledge structures in problem solving process. The students connect their existing knowledge with new circumstances they come across, and construct new knowledge structures accordingly (Bodner, 2007). In other words, it is possible to help students develop their knowledge structures by using appropriate pedagogical strategies (Bischoff et al., 2010).

Although researchers used different ways to reveal knowledge structure of the learners, word association test (WAT) is one of the most appropriate tools for revealing the development in their knowledge structures (Gulacar et al., 2015). Investigating changes in undergraduate students' knowledge structure through WATs during the learning process in a general chemistry course, Nakiboglu (2008) informed that significant changes occurred in their knowledge structure before and after the instruction.

In a similar vein, Bahar et al. (1999) analyzed students' knowledge structure in elementary genetics by using WATs after the teaching session. Based on the results, they noted that it is a powerful technique for revealing the type and number of concepts in students' minds as well as the links between them. WATs were also used in the current study to observe differences in the students' knowledge structures before and after the implementation of Robotic Modeling: The Mars Mission STEM-LEAP.

This study differs from the existing literature in multiple aspects and is hope to fill the related research gap. Namely, STEM-LEAP applied in the study was designed as a summer camp to encourage the motivation of voluntary participation in out-of-school learning environments. The six-day training was designed based on the P3 task taxonomy in which robotic, modeling, and art-design contents would be presented. In addition, the Mars Mission was chosen as the context problem situation. STEM-LEAP is designed in a unique structure in terms of content. Few studies in the literature revealed that Summer Robotics Camps develop students' engineering career interest (Ayar et al. 2013; Yan et al., 2020). It is predicted that the content applied in this study would develop students' career interests in other fields (science, technology, mathematics) besides engineering.

Although the relevant literature shows that the female students' awareness of engineering can be increased by being exposed to successful female role models (Plant et al., 2009), perceptions that STEM fields require high-level mathematics and science content knowledge lead to a loss of confidence in these fields and weaken their career interests (Dave et al., 2010). STEM-LEAP is designed to appeal to all students irrespective of their gender due to the content features described above (robotics, modeling and art & design). In this respect, it is one of the valuable aspects of this study to examine whether this development differs in areas where the students' STEM career interest develops regarding gender.

In the present study, STEM-LEAP was employed as a program wherein the students took an active part as well as responsibility in the learning process, and contributed to the solution of problems using their cognitive skills. Therefore, the program was expected to contribute to the development of the students' knowledge structures. It was predicted that identification of these knowledge constructs with reference to the conceptual transformation introduced through the contents of STEM-LEAP could help the researchers assess the effectiveness of STEM-LEAP.

2.3. Research Questions

The present study focused on the implementation and assessing the effectiveness of Robotic Modeling: The Mars Mission STEM-LEAP as an integrated STEM learning program. In line with the research objective, the following research questions were addressed:

RQ 1) Does Robotic Modeling: The Mars Mission STEM-LEAP intervention affect students' STEM career interest?

RQ 2) Does gender moderate the effects of the Robotic Modeling: The Mars Mission STEM-LEAP intervention on students' STEM career interest?

RQ 3) How do students' knowledge structures change during the Robotic Modeling: The Mars Mission STEM-LEAP?

3. Method

The present study focused on the assessment of the Robotic Modeling: The Mars Mission STEM-LEAP Learning Program designed for 7th grade students who were supposed to work on a STEM-related problem case through modeling and design activities. Employing investigation strategies that involve simultaneous or sequential data collection (Creswell & Plano Clark, 2007), the mixed method was utilized in this study for providing better responses to the research questions. Specifically, it was designed as a quantitative one as it focused on the effects of an experimental intervention, and a qualitative one as it sought to identify the students' conceptual constructs. The students were expected to develop basic robotics and design skills through the six-day event Robotic Modeling: The Mars Mission STEM-LEAP, to develop these skills in problem solving processes and to employ them in project design by using them to solve real life problems. For this purpose, the content of Robotic Modeling: The Mars Mission STEM-LEAP was designed in the alignment of P3 Task taxonomy which is frequently employed in engineering education.

3.1. Robotics in the STEM-LEAP

This study exclusively employed LEGO EV3 robotics sets, one of the most widely used tools in robotics activities. LEGO EV3 robotics sets are extensively utilized in STEM education at the K-12 level, given their various benefits in developing the children's problem solving skills, presenting practical applications of the principles of science, providing means for engineering applications, facilitating the development of reasoning and spatial skills as well as mathematical thinking on part of the children (Carbonaro et al., 2004; Castledine & Chalmers, 2011).

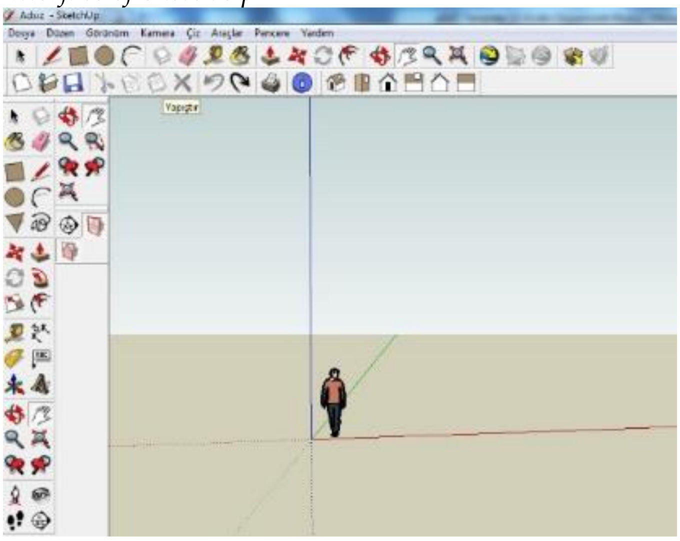
LEGOs make it more enjoyable, effective and collaboration-based for students to develop building, design and programming skills. Robots built using LEGOS help teaching the basic concepts of engineering and technology. LEGO robots not only help the students develop mathematical thinking skills, cooperative work skills, creativity and problem solving skills also facilitate their understanding of the scientific methods, logic of programming, and engineering design processes. In addition, LEGO EV3 sets were a rather obvious choice for this study as LEGO parts are robust and easily programmable. In the STEM learning program implemented in this study, "The Mars Mission" served as the context of the problem case presented to the students. The students were asked to develop models of vehicles capable of moving in a rock-covered canyon on the surface of the Mars. It is noteworthy that LEGO EV3 robotics sets have the structural characteristics to enable the design of these models.

3.2. SketchUp Software and Spatial Thinking in the STEM-LEAP

Spatial thinking plays a central role in integrating robotics and astronomy. The spatial thinking skill, which is the building block of spatial thinking refers to the ability to imagine an image in one's mind, to alter and put to use that image (Lord, 1985), to produce a visual image, and to proceed with, to revise, and to transform an existing form. People need the spatial thinking for basic necessities such as rearranging the furniture at home, or maneuvering or stopping the car as part of a safe-driving experience, in our daily lives (Rafi et al., 2008). Ben-Chaim et al. (1988) underline the importance of spatial visualization –a major component of spatial thinking skills–in most technical-scientific professions in general, and STEM-related fields in particular. Astronomy, in its turn, represents a domain of knowledge providing an interdisciplinary combination of all fields of STEM. To be able to grasp various topics and concepts of astronomy, one needs spatial thinking skills such as imagining objects from different angles, tracking their movement through multi-dimensional space, and reasoning about the representations of stellar objects (Cole et al., 2018).

LEGO is often compared to SketchUp® software, in the context of enabling students to express their spatial skills. SketchUp® is a three dimensional modeling software, and is used in graphic design, engineering, as well as architecture (Murdock, 2009). Moreover, the geometry features of the software entails elements focusing on certain skills such as developing focus, templates, transformations, and spatial skills, all of which serve the purposes of software development (Fleron, 2009; Kurtulus & Uygan, 2010). The interface of SketchUp® involves axes in three dimensional space, and a human model for the modeling and tools used for building (see Figure 1).

Figure 1
Interface of SketchUp

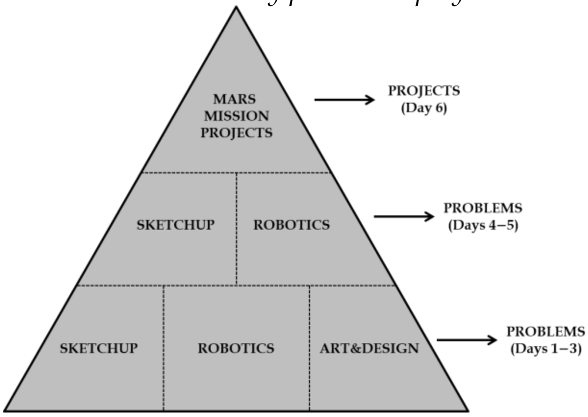


The software is comprised of certain basic tools used frequently. These include the "rotate" tool allowing the user to rotate an object at certain angles from specified axes, the "pan" tool letting the user to slide the view on the vertical or horizontal axis, the "position camera" tool enabling the positioning of the camera used to display the objects on the screen, the "look around" tool allowing the user to look at the shapes from a certain point specified on the screen, and the "orbit" tool allowing the spinning of the whole screen to see the objects from all angles possible. As all these tools inherently support spatial skills, they can be used for modeling geometric shapes and 3D elements. SketchUp applications used in STEM-LEAP have been used to develop students reasoning, spatial skills, building and design skills.

3.3. P3 Task Taxonomy

In the present study, the students were expected to implement a task taxonomy, in order to facilitate access to the project activities provided to them. P3 Task Taxonomy provided the model employed for this purpose. This taxonomy was developed by Kastelan et al. (2014) and initially used to develop an education system with a focus on computer science at the university level, and was subsequently revised by Barak and Assal (2018) who employed the taxonomy in three steps (Practice, Problems, Projects). In the present study, P3 Task Taxonomy was chosen as the optimal tool in terms of revealing how previous learning experiences can facilitate the performance of new tasks, and how otherwise complex tasks can be handled with relative ease. The model is presented in Figure 2.

Figure 2
The P3 Task Taxonomy process employed



In the Practice step, the students engage in exercises with already known solutions, as well as in closed-ended tasks, trying to come up with the correct answer, and gain experience while doing so. In the Problem Solving (or Problems) step, they are given small-scale open-ended tasks which can be handled through various distinct approaches to come up with different answers. Finally, the Projects step expects them to handle rather complicated tasks. At this step, the students are expected to define the problem, identify the objectives, and implement the solution.

The Practice step of STEM-LEAP took three days (Days 1 to 3). This time frame involved SketchUp, Robotics, Art and Design trainings. The Problem Solving step, in turn, entailed two days (Days 4 and 5) of SketchUp and Robotics trainings. Finally, the Projects step lasted a single day (Day 6) and required observing the students work on the problem case of the Mars Mission, as was presented to them. The steps in concern are presented in detail in the following sections.

3.3.1. Step 1. Practice

In the Practice step, the students are expected to receive basic knowledge and skills about Robotics and SketchUp. Furthermore, the Art and Design activities carried out in this step are intended to develop creative designs (see Appendix). *Robotics and Coding:* In the context of the Robotics training, the students began with discovering the basic parts of Lego EV3. They were initially introduced to ultrasonic, color, gyro and touch sensors and motors included in the set, and led to produce simple mechanical structures as they had not used LEGO EV3 earlier. Furthermore, the students were given a chance to experience LEGO EV3 block coding in order to improve their algorithm development skills, and to learn to use the software language.

3.3.2. SketchUp

In this step, the students got acquainted with the interface of SketchUp 3D design and modeling software. They also experienced the 3D model building skills. They learned how to use the toolbars for design. In this step, the basic settings and drawing logic of SketchUp were introduced, along with the use of commands such as select, move, rotate, and zoom, to provide them the ability to control the screen, the camera position, and the view.

3.3.3. Art and Design

The Art and Design step involved various activities around the Mars and space themes, with a view to supporting the students' creative design skills. In the activity titled "My Dream Martian", the students produced a 3D the Mars design using a material named Plastimake. Thanks to this activity, they developed certain skills such as reasoning the ratio and proportion of the human figures, discerning geometric forms in moving human figures, and using their imagination to come up with new life form visions. The activity titled "My First Day on the Mars", on the other hand, required them to imagine their first day on the Mars, and to create a comic book out of it, using Pixton, a Web 2.0 service. Finally, the "UFO I Found in the Garbage" activity involved the building of a 3D space vehicle, using waste materials. The Art and Design activities were not part of the subsequent steps.

3.3.4. Step 2. Problems

In this step, the students engaged in small-scale open-ended tasks, which provided them the opportunities to employ various solutions in Robotics and Coding and SketchUp activities (see the Appendix). *Robotics and Coding:* The Robotics activities allowed the students to develop coding skills for various problem cases by using the sensors, motors and EV3 Mindstorms interface which were introduced in the first step. The students chose the introduction-level training robot using the Robot Educator-Building Instructions tab, and proceeding with the steps provided. Using that robot, the students practiced with simple tasks such as "*if there is an object within 20 cm in front of you, turn on the red light and turn right, if not, proceed straight*", "*proceed on the white line on the black surface*", "*move when you hit the Touch 1 sensor; stop when there is an object 40 cm ahead of you*", "*turn 90 degrees to the right if there is an object 30 cm ahead of you, then proceed straight*", or "*start the medium motor when the color sensor notices red*". Thus, the students were equipped with the background and skills required to design the autonomous robot to serve on the platform where the problem scenario of the study would be applied in Step 3.

3.3.5. SketchUp

In this step, the students worked with basic geometric shapes, using the commands they practiced in the first step. In this context, various 3D shapes such as prisms, pyramids, cones, spheres of various sizes were constructed. The students then took horizontal, vertical, and sloped cuts of these objects, and analyzed the cross-sections. Having gained necessary experience with geometric shapes, the students were then asked to design a Mars Home of a size of their own choosing, provided that it was big enough for two people. Through this task, the students developed the essential knowledge for the mission identified in Step 3.

3.3.6. Step 3. Projects: The Mars Mission

In this section, the students were presented with the following problem case, and asked to design projects to handle it.

> Problem statement: A rover was sent to the Mars, to perform some studies of its surface. However, due to some glitch, the vehicle landed to a location far from the base it was supposed to land in. To reach the base where the studies are to be performed, the vehicle should go through a canyon with various obstacles en route. You are now expected to design this autonomous vehicle and modeling the canyon, to ensure that the vehicle successfully moves through the canyon and reaches the base.

The students were issued a presentation file describing the problem case of the scenario, and perform a detailed analysis of the model of the landscape where the mission is expected to be carried out, taking relevant notes in detail. LEGO Mindstorms Education EV3 and LEGO Mindstorms Education EV3 add-on sets were provided to the students, who were asked to design an autonomous space vehicle capable of meeting all mission requirements at once. The groups then proceeded with modeling the platform for the Mars Mission scenario, making use of their previous robot design practices and 3D drawings produced in Steps 1 and 2. Then, they used the platform to test the robots they developed. The students tested the dimensions of the robot to go through the canyon, using 3D drawings. Then they debated the advantages and disadvantages of various robots which were able to complete the mission. They also made significant efforts to overcome the new problems they encountered in developing an autonomous robot which met the requirements of the problem case (see Appendix).

3.4. Participants

The participants of the STEM-LEAP activity, which was organized in a 6-day summer camp format, were students who just completed 7th grade, to proceed to the 8th. The announcements promoting the STEM-LEAP program were delivered to schools throughout the province. The students who wished to take part in the program notified the program organizers with the help of school administrators. The applicants for the program were then reviewed in terms of their motivation, expressed interest in science, physical ability to cope with the intensive program to be applied at the training, and lack of any outstanding health problems to preclude attendance, culminating in the selection of 32 participants from nine schools. 15 of the selected participants were females, and 17 were males. All participants were either 12 or 13 years old. The students handled Steps 1 and 2 as individuals, and then in Step 3, worked on the project in groups of four.

3.5. Data Collection

3.5.1. STEM career interest scale

To assess influence of the STEM-LEAP on the students' interest in a career in STEM, the STEM Career Interest Survey/STEM-CIS developed by Kier et al. (2014) was used. The scale covers four sub-dimensions (Science, Technology, Engineering and Mathematics). As part of their efforts to translate the scale into Turkish, Koyunlu-Unlu et al. (2016) applied it to 1033 secondary school students, verifying its structure based on four sub-dimensions and 40 items. The Cronbach's alpha internal consistency factor of the scale was found to be .93 for the overall scale, .86 for science sub-dimension, .88 for technology sub-dimension, .94 for engineering sub-dimension, and .90 for mathematics sub-dimension. It is noteworthy that no further validity and reliability analyses were conducted as the sample of the present study and that of the study which adopted the original scale to the Turkish language were similar in age. STEM Career Interest Survey was applied as a pretest before the program, and as a posttest after the program.

3.5.2. Word association test

In order to assess STEM-LEAP's potential influence on students' knowledge structures, word association test (WAT) was applied both as a pretest and a posttest. The WAT can be used before instruction to probe the prior concepts in students' knowledge structure as well as after instruction (Bahar et al., 1999; Johnstone & Moynihan, 1985; Shavelson, 1972). The WAT used the keywords the students were expected to come across within the framework of Robotic Modeling: The Mars Mission STEM-LEAP. The keywords were separately chosen from the concepts that the program was built on and that were considered most important to the subject, and finalized by the consensus of the three researchers. In conclusion, *coding, modeling, problem, robot, design* and *space* concepts were used as the foundation of the WAT design.

On the first day of the program, the students were provided a description of WAT, and given one minute for each concept to be covered. Usually, the responses regarding each concept in the WAT are extended within thirty seconds (Bahar et al., 1999). However, as the participants of the present study were secondary school students, they were given one minute for each keyword. Within the given period, they wrote down the words they associated with the keyword in question. Subsequently, they were given the following keywords: "coding, modeling, problem, robot, design and space" one after other. Once the time given for a keyword ran out, they were asked to proceed right away to the next keyword, so as to ensure that each keyword was given an equal amount of time to consider.

The same procedure was repeated after the program in the form of a posttest. The elicited responses were individually analyzed because they, when associated with the key concepts, may be a product of evocation that is not significantly correlated with the key concept. Besides, since a sentence is much more complex and advanced than a single word, the evaluation process is influenced by situations whether the sentence is scientific or not, or whether it involves misconceptions or not.

3.6. Data Analysis

The normality of the distributions and the homogeneity of the variances regarding the pre-test and post-test scores obtained from the scale were tested. Since the Shapiro-Wilk test results of the pretest and post-test scores were not significant in all domains ($p > .05$), the assumption of normality was provided. An F value was calculated for each subscale. Levene homogeneity test indicated that the variances were homogeneous ($p > .05$). In small-group experimental studies, it is stated that parametric tests can be used because they are more reliable than non-parametric tests if the distribution of data is appropriate and assumptions are met (Pett, 2007). In this study the paired sample t-test was performed to compare the results of the pretest and posttest on the students' interest in a career in any STEM field (Science, Technology, Engineering and Mathematics). The two-way ANOVA test was applied to observe the effect of gender in the STEM field, where significant differentiation was observed according to this test result. Finally, the SPSS package program was used in all quantitative analyzes.

C*oding, modeling, problem, robot, design* and *space* concepts were used as the foundation of the word association test design. In the study, semantically similar responses were combined/grouped and their frequencies were calculated. Thus, the words with semantic similarity were grouped and categories were created and the categories were named according to what the answer words in the categories meant. The irrelevant words were excluded from the categories. During these processes, the words were categorized based on the criterion of semantic similarity, and the frequencies of the words in each category were calculated and tabulated. The associated word numbers were schematized according to the pre-test and post-test results. The number of words associated by students was shown above the arrows. In this way, it was shown in which words a more intense relationship was established.

To obtain reliability of the analysis, responses elicited from all WATs were analyzed and a concept map was drawn from the WAT results by the two authors, independently. In the analysis of the WAT data, the Miles and Huberman's (1994) reliability formula [Reliability = Consensus / (Agreement + Disagreement)] was used, and the inter-rater agreement was found 95%, confirming the reliability of the analysis.

4. Results

4.1. Results of the STEM Career Interest Survey

The paired sample t test was carried out to see if the STEM-LEAP program affected the students' interest in a career in STEM fields. The sub-fields where the test results showed a certain amount of variation were subjected to further investigation using the two-factor variance analysis for complex measurements in order to reveal if the students differ in their STEM career interest regarding gender. Table 1 presents the paired sample t test results in concern.

Table 1
Results of the Paired Sample t-test on the Students' Career Interest in STEM Fields

		Pre-test		*Post-test*				
Sub-Scales	*N*	*M*	*SD*	*M*	*SD*	*df*	*t*	*p*
Science	32	41.80	4.94	43.19	4.15	31.00	−1.883	.069
Technology	32	41.30	6.21	42.53	5.17	31.00	−1.345	.188
Engineering	32	33.85	7.23	39.97	7.73	31.00	−5.528	.000
Mathematics	32	42.55	6.20	42.88	6.91	31.00	−.409	.685

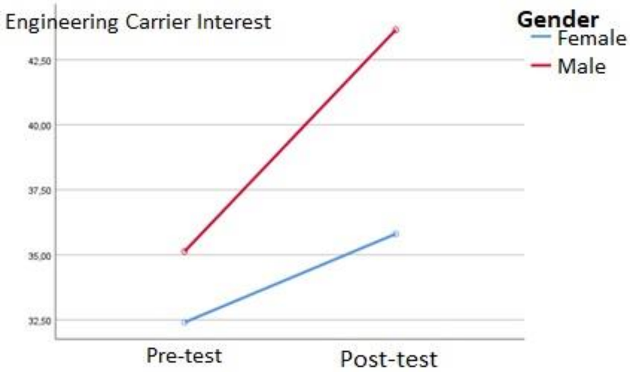
Table 1 reveals that the students' interest in a career in any STEM field has significantly increased. Yet, the change in their interests in a career in Science, Technology or Mathematics is not statistically significant, whereas their interest in a career in Engineering increased significantly [$t(31)=-5.528$. $p<.05$]. As of the end of the program, the students' interest in a career in Engineering grew substantially. Two-way ANOVA was applied to see if this change had to do with the variable of gender. The descriptive analysis results are presented in Table 2.

Table 2
The Change in the Students' Interest in a Career in Engineering, Based on Their Gender

		Pre-test		*Post-test*	
Gender	*N*	*M*	*SD*	*M*	*SD*
Female	15	32.40	8.33	35.80	9.15
Male	17	35.12	6.04	43.64	3.42

The analysis revealed significant differences between the pretest and posttest results of the students $[F(1-30) = 33.74, p < .05]$. Moreover, a significant variation was observed across gender, with the male students experiencing an increased interest in a career in engineering $[F(1-30) = 5.53, p < .05]$. Similarly, gender by measurement-time interaction was statistically significant $[F(1-30) = 6.22, p < .05]$. In the light of the data presented, it is evident that the activities included in the program led to an increase in all participating students' interest in a career in engineering. However, the increase was more marked with the male students when compared to the female students. The rates of the change observed are presented in Figure 3.

Figure 3
Career interest change as a function of gender by measurement time interaction



4.2. Results of the Word Association Test

The Word Association Test (WAT) was applied in the form of a pretest and posttest. To prevent any confusion in the presentation of the findings, the concepts presented to the students were labeled "keywords", whereas the words the students associated with these words were labeled "responses". The number of responses provided by the students in the process is presented in Table 3.

Table 3
Number of Responses Associated with Keywords

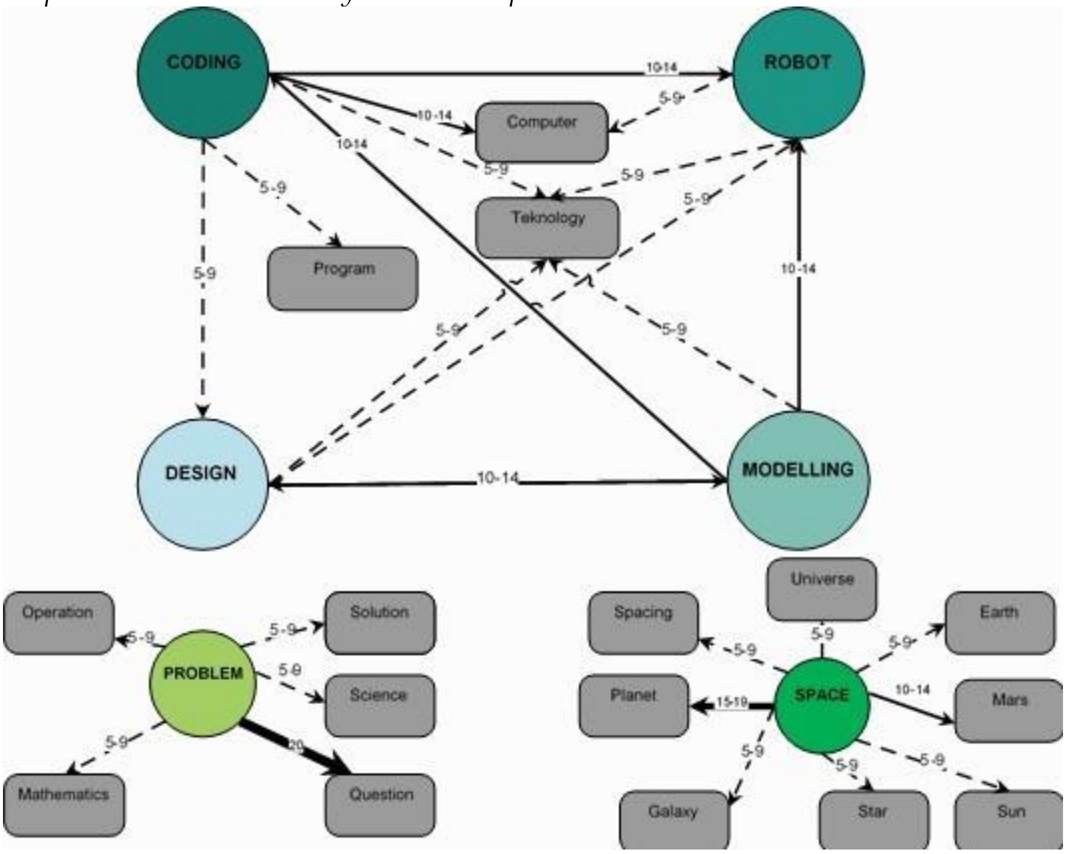
	Number of Responses	
Keywords	*Pre-test*	*Post-test*
Coding	131	175
Design	127	162
Problem	139	180
Modeling	123	161
Space	165	234
Robot	129	194
Total	**814**	**1106**

It is evident from Table 3 that 814 and 1106 responses were provided by the students in the pretest and posttest, respectively. STEM-LEAP implementation led to an apparent increase in the number of responses associated with all keywords. Such an observation indicates an improvement in grasping the keywords.

The tabulated responses obtained from the pre-test are presented in the concept grid (see Figure

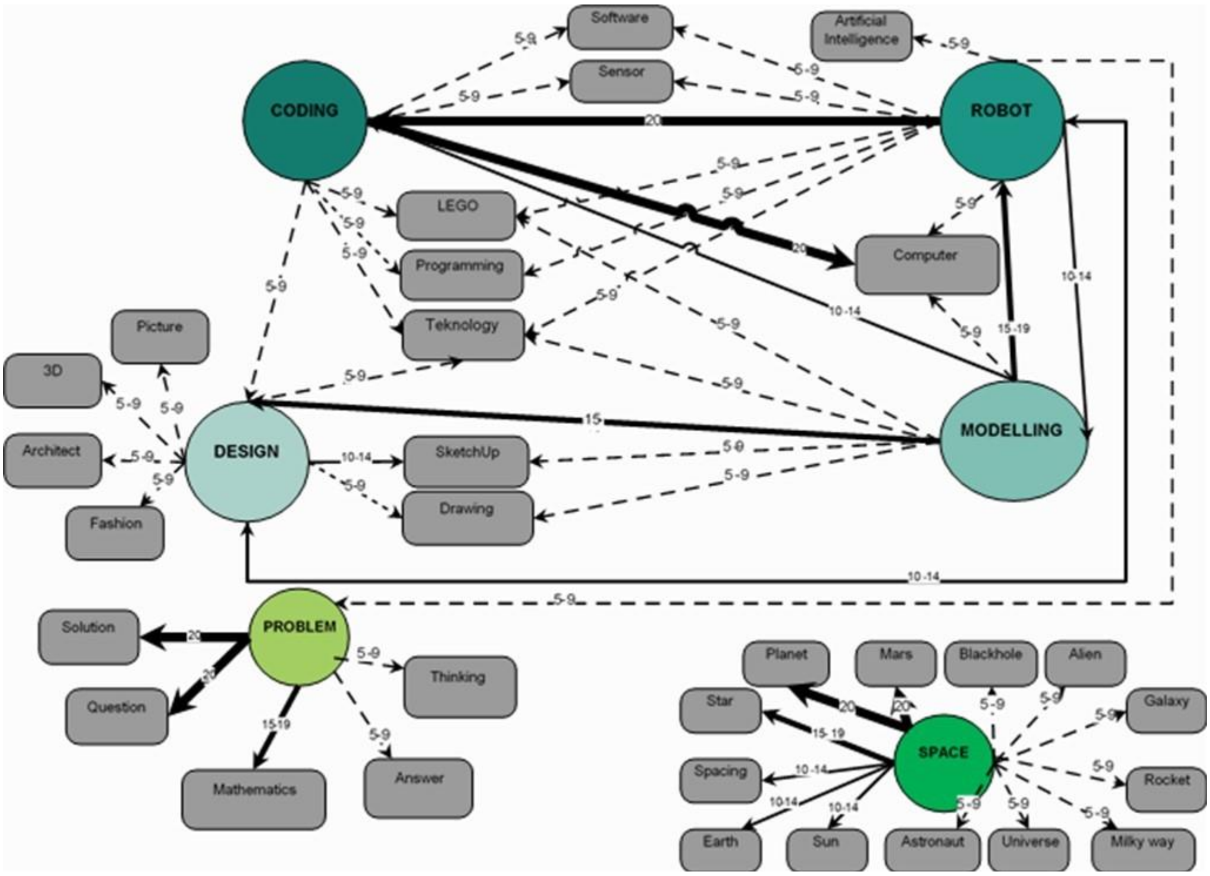
4). The shape and thickness of the arrows denoting associations are based on the break points in order to provide a clearer picture of the relationship between the keywords and the responses as presented in the concept grid. For instance, the associations between the keywords/responses with a break point in the 5-9 range were shown with dashed lines (⇢) whereas the associations between the keywords/responses with a break point equal to or higher than 20 were shown with thick arrows (→).

Figure 4
Responses associated with keywords in the pretest



The strongest association shown in Figure 4 is the one between "problem and question" (with a break point higher than 20). In other words, more than 20 participants associated the keyword "problem" with the response "question". This break point was reached with only a single response. A response with a break point in 15-19 range was "planet". One should also note that the response word "planet" was associated only with the keyword "space". On the other hand, the number of the responses associated with the keywords in the break point range 10-14 was remarkably higher. Moreover, associations in this range began to appear between individual keywords (i.e. the keyword "coding" was associated with not only the response word "computer", but also with other keywords, namely "robot" and "modeling"). The 5-9 break point range is notable with the prominence of the associations between all keywords as well as the relevant responses. The concept grid based on the keywords elicited from the posttest is presented in Figure 5. Similar to the pretest, the shapes of the arrows used in the grid differ across the cut-off points.

Figure 5
Responses associated with keywords in the posttest



A glance at Figure 5 indicates a more intensive relationship between the keywords. A similar increase in the intensity was observed in the associations between the keywords and the responses. In the break point range of 20 or more, the keyword "coding" was associated with the keyword "robot", and the response word "computer". In the same range, the keyword "problem" was found to be associated with the response words "solution" and "question", whereas the keyword "space" was associated with the response words "planet" and "the Mars". In the break point range 15-19, the keyword "modeling" was found to be associated with the keywords "robot" and "design". Again, in this range, the keyword "space" was found to be associated with the response word "star", and the keyword "problem" was associated with the response word "mathematics". In the break point range 10-14, associations were observed between the keywords "coding" and "modeling" as well as "robot" and "modeling". The highest number of associations in this range was noted with the keyword "space". Here, the students associated the keyword with the response words "spacing", "the earth", and "the sun". The associations among the keywords were mostly frequented in the cutting intervals of 5 and 9. In this range, each keyword was found to be associated with at least one response word.

5. Discussion and Conclusion

The present study focused on the implementation and assessing the effectiveness of Robotic Modeling: The Mars Mission STEM-LEAP as an integrated STEM learning program. The study exclusively investigated the effect of the STEM-LEAP on the students' interest in a career in STEM as well as their knowledge structures. The fundamental purpose of the STEM education is to train professionals needed in the fields of science, technology, engineering, and mathematics. The National Research Council (2011) reported that the number of professionals trained for a career in STEM fields is insufficient to meet the United States' increasing need for individuals with technical training and scientific literacy. In Turkey, a developing country with the youngest population of all Europe, the need for a qualified work force well-versed in STEM fields is apparent.

Recent studies revealed the need for improving the students' attitudes towards and achievement levels and interest in STEM fields as a must for increasing their level of interest in a career in STEM (Dabney et al., 2012; Hayden et al., 2011; Lavonen et al., 2008). The present study reported that the STEM-LEAP significantly influenced the students' career interest in engineering while it was not effective enough (was not sufficient) to reinforce their interest in a career in science, technology and mathematics. The STEM-LEAP was implemented as a summer camp as an extracurricular activity. The existing literature notes that extracurricular science activities (Dabney et al., 2012), STEM competitions (Miller et al., 2017) and STEM robotics club organizations (Nugent et al., 2016) increase the students' interest in a career in STEM. These studies, however, did not try to identify the specific sub-field of STEM marked by the most significant increase in interest in a career. On the other hand, Nugent et al. (2016) stated that Lego Robotics activities implemented independent of the curricular activities at school helped increase interest in a career in engineering. Arguably, the explicit inclusion of the robotics activities in all three steps of P3 task taxonomy (Practice, Problems, Projects) led to such activities drawing more interest compared to the activities focusing on art and design and mathematical modeling (SketchUp), and thus, an increased emphasis on the interest in a career in engineering compared to a career in other domains of STEM. The Mars Mission project drew the students' interest and attention to this issue, but it did not go far in terms of increasing their level of interest in a career in science. In the same vein, the students' interest in a career in mathematics was not increased either despite spending some time on mathematical modeling (SketchUp). The contribution of robotics and art and design activities to the technology domain of STEM was also limited.

The study also investigated the influence of the STEM-LEAP on the students' interest in a career in engineering, with reference to their gender. In this context, the male students were observed to enjoy a higher level of increase in their interest in a career in engineering than the female students. Underrepresentation of women in science, technology, engineering and mathematics (STEM) stands out as a point of concern for most societies (Meyer et al., 2015). It is noted that, within the wider framework of STEM fields, women are more interested in human biology, health and fitness, while men are more interested in science, technology and the destructive aspects of science and technology (Christidou, 2006). Again, it is noted that extracurricular robotics competitions increase men's interest in a career in STEM, compared to the level of increase registered in women's interest in a career in STEM, arguably due to the more competitive nature of men when compared with women (Miller et al., 2017). The present study also reached to the argument that working in competition with other groups in the project step of P3 task taxonomy led to a rather striking increase in the male students' interest in a career in engineering. On the other hand, few studies evidenced that STEM activities entailed no significant difference in the increase in career interest regarding gender (Dabney et al., 2012).

WATs were applied before and after the STEM-LEAP, in order to assess the change in the students' knowledge structures. The students were presented with the keywords Coding, Design, Problem, Modeling, Space, and Robot, in the respective order, and asked to associate them with specific terms. 814 and 1106 responses were provided by the students in the pretest and the posttest, respectively. The number of the terms with which these keywords were associated was increased by approximately 36% in the posttest. The WAT can be used before instruction to probe the prior concepts in students' knowledge structure as well as after instruction (Bahar et al, 1999; Johnstone & Moynihan, 1985; Shavelson, 1972). The results of the WATs indicated positive changes in the students' knowledge structures. These important changes before and after the STEM-LEAP activity may be attributed to effect of the activity on the students' knowledge structures by constructing a network and establishing new associations response words. Similar findings were also reported in previous studies (Cachapuz & Maskill, 1987; Nakiboglu, 2008).

The terms associated with the STEM-LEAP keywords are also significant in terms of their diversity. For instance, the number of response words associated with the keyword "space" in the pretest rose from eight to thirteen in the posttest. Such a change observed in the posttest was also accompanied by an increase in strong associations. In the pretest, the association between problem and question, and space and planet were the exceptions with a break point of 15 or higher (denoting a strong association). In contrast, in the posttest the associations between robot and coding, coding and computer, modeling and design, problem and question, problem and solution, problem and mathematics, space and star, space and planet, and space and the Mars also stood out as strong associations. These changes suggest that the STEM-LEAP helped enhance the students' knowledge structures, and shape the associations between various concepts. As noted in the previous studies, robotics summer camps encouraged students towards greater proficiency in STEM fields in terms of their knowledge of engineering, engineering design, and programming (Nugent et al., 2016). Moreover, it is also understood that STEM camps as informal learning environments helped the students develop content knowledge regarding the topics they work on (Mohr-Schroeder et al., 2014). The present study led to the conclusion that activities planned with reference to the Mars mission scenario with the aim of integrating STEM fields with P3 task taxonomy facilitate the development of the students' knowledge structures.

6. Suggestions and Implications

Even though there are different approaches to the STEM education around the globe, the present study still stands out with the tried and tested model based on a successful integration of the Robotics, Art and Design, and Mathematical Modeling (SketchUp) on the basis of P3 Task Taxonomy (Practice, Problems, Projects). Hands-on activities implemented within the framework of the STEM education are known to be interesting to the students (Nugent et al., 2016). For a holistic contribution for the students, these activities should be pedagogically designed and integrated with STEM fields including robotic applications with a focus on real-life problems.

The education activity provided in the context of this study reinforced the students' interests in a career in engineering in particular. Subsequent studies may follow up with alternative activities to foster their interest in other STEM fields through the STEM education involving robotics applications. The intervention increased the male students' interest in engineering career more than the female students. Although the STEM-LEAP is designed to appeal to all students irrespective of their gender, it did not have the same effect on the career interests of male and female students. The results of this study suggest that researchers use different opportunities to experience practices that will transform career interests in favor of female students.

In the study, strong connections were observed between four key concepts (coding, design, modeling and robot) as a reflection of the development in the students' knowledge structures. However, it has been observed that the concepts of "problem" and "space" are barely associated with these four concepts. Since the observation of certain conceptual relationships was not defined as a learning goal in this study, the STEM-integrated robotics curriculum developers can define the change in knowledge structures as a learning goal and adjust the content accordingly.

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References

Ayar, M., Yalvac, B., Uğurdağ, H. F., & Şahin, A. (2013). A robotics summer camp for high school students: pipelines activities promoting careers in engineering fields. *In 2013 ASEE Annual Conference*. American Society for Engineering Education.

Bahar, M., Johnstone, A. H., & Sutcliffe. R. G. (1999). Investigation of students' cognitive structure in elementary genetics through word association tests. *Journal of Biological Education, 33,* 134-141. https://doi.org/10.1080/00219266.1999.9655653

Barak, M., & Assal M. (2018). Robotics and STEM learning: students' achievements in assignments according to the p3 task taxonomy-practice, problem solving, and projects. *International Journal of Technology and Design Education, 28*(1), 121-144. https://doi.org/10.1007/s10798-016-9385-9

Ben-Chaim, D., Lappan, G., & Houang, R. T. (1988). The Effect of instruction on spatial visualization skills of middle school boys and girls. *American Educational Research Journal, 25,* 51-71. https://doi.org/10.3102/00028312025001051

Benitti, F. B. V. (2012). Exploring the educational potential of robotics in schools: A systematic review. *Computers & Education, 58*(3), 978-988. https://doi.org/10.1016/j.compedu.2011.10.006

Bischoff, P. J., Avery, L., Golden, C. F., & French, P. (2010). An analysis of knowledge structure, diversity and diagnostic abilities among pre-service science teachers within the domain of oxidation and reduction chemistry. *Journal of Science Teacher Education, 21*(4), 411–429. https://doi.org/10.1007/s10972-010-9188-x

Bodner, G. M. (2007). Strengthening conceptual connections in introductory chemistry courses. *Chemistry Education Research and Practice, 8,* 93-100. https://doi.org/10.1039/B4RP90007C

Cachapuz, A. F. C., & Maskill R. (1987). Detecting changes with learning in the organization of knowledge: Use of word association test to follow the learning of collision theory. *International Journal of Science Education, 9*, 491-504. https://doi.org/10.1080/0950069870090407

Carbonaro, M., Rex, M., & Chambers, J. (2004). Using LEGO robotics in a project-based learning environment. *The Interactive Multimedia Electronic Journal of Computer-Enhanced Learning, 6*(1). http://www.imej.wfu.edu/articles/2004/1/02/index.asp

Castledine, A. R., & Chalmers, C. (2011). LEGO Robotics: An authentic problem solving tool? *Design and Technology Education: An International Journal, 16*(3), 19-27.

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

Christidou, V. (2006). Greek students' science-related interests and experiences: Gender differences and correlations. *International Journal of Science Education, 28*(10), 1181-1199. https://doi.org/10.1080/09500690500439389

Clariana, R. B. (2010). Multi-decision approaches for eliciting knowledge structure. In D. Ifenthaler, P. Pirnay-Dummer, & N. M. Seel (Eds.), *Computer-based diagnostics and systematic analysis of knowledge* (pp. 41-59). Springer. https://doi.org/10.1007/978-1-4419-5662-0_4

Cole, M., Cohen, C., Wilhelm, J., & Lindell, R. (2018). Spatial thinking in astronomy education research. *Physical Review Physics Education Research, 14,* 010139. https://doi.org/10.1103/PhysRevPhysEducRes.14.010139

Conrad, J., Polly, D., Binns, I., & Algozzine, B. (2018). Student perceptions of a summer robotics camp experience: The clearing house. *Journal of Educational Strategies*, *91*(3), 131-139. https://doi.org/10.1080/00098655.2018.1436819

Creswell, J. W., & Plano Clark, V. L. (2007). *Designing and conducting mixed methods research*. Sage.

Dabney, K. P., Tai, R. H., Almarode, J. T., Miller-Friedmann, J. L., Sonnert, G., Sadler, P. M., & Hazari, Z. (2012). Out-of-school time science activities and their association with career interest in STEM. *International Journal of Science Education, Part B, 2*(1), 63-79. https://doi.org/10.1080/21548455.2011.629455

Dave, V., Blasko, D., Holliday-Darr, K., Kremer, J. T., Edwards, R., Ford, M., & Hido, B. (2010). Re-enJEANeering STEM Education: Math options summer camp. *Journal of Technology Studies*, *36*(1), 35-45.

Davis, K. B., & Hardin, S. E. (2013). Making STEM fun: How to organize a STEM camp. *Teaching Exceptional Children,45*(4), 60–67. https://doi.org/10.1177/004005991304500408

Fleron, J. F. (2009). *Google SketchUp: A powerful tool for teaching, learning and applying geometry*. Retrieved from http://www.wsc.ma.edu/math/prime/concrete.ideas/GSUPaperNCTM.pdf

Furner, J., & Kumar, D. (2007). The mathematics and science integration argument: a stand for teacher education. *Eurasia Journal of Mathematics, Science and Technology, 3*(3), 185-189. https://doi.org/10.12973/ejmste/75397

Gulacar, O., Sinan, O., Bowman, C. R., & Yildirim, Y. (2015). Exploring the changes in students' understanding of the scientific method using word associations. *Research in Science Education, 45(5),* 717-726. https://doi.org/10.1007/s11165-014-9443-9

Hammack, R., Ivey, T. A., Utley, J., & High, K. A. (2015). Effect of an engineering camp on students' perceptions of engineering and technology. *Journal of Pre-College Engineering Education Research*, *5*(2), 1-12. https://doi.org/10.7771/2157-9288.1102

Hayden, K., Ouyang, Y., Scinski, L., Olszewski, B., & Bielefeldt, T. (2011). Increasing student interest and attitudes in STEM: Professional development and activities to engage and inspire learners. *Contemporary Issues in Technology and Teacher Education, 11*(1), 47-69.

Johnstone, A. H., & Moynihan T. F. (1985). The relationship between performances in word association tests and achievement in chemistry. *European Journal of Science Education, 7*, 57-66. https://doi.org/10.1080/0140528850070106

Kastelan, I., Benito, J. R. L., Gonzalez, E. A., Piwinski, J., Barak, M., & Temerinac, M. (2014). E2LP: A unified embedded engineering learning platform. *Microprocessors and Microsystems, 38*(8), 933-946. https://doi.org/10.1016/j.micpro.2014.09.003

Kier, M. W., Blanchard, M. R., Osborne, J. W., & Albert, J. L. (2014). The development of the STEM career interest survey (STEM-CIS). *Research in Science Education, 44*(3), 461-481. https://doi.org/10.1007/s11165-013-9389-3

Kim, K., & Tawfik, A. A. (2021). Different approaches to collaborative problem solving between successful versus less successful problem solvers: Tracking changes of knowledge structure. *Journal of Research on Technology in Education*. https://doi.org/10.1080/15391523.2021.2014374

Kopcha, T. J., McGregor, J., Shin, S., Qian, Y., Choi, J., Hill, R., Mativo, J., & Choi, I. (2017). Developing an integrative STEM curriculum for robotics education through educational design research. *Journal of Formative Design in Learning, 1*(1), 31-44. https://doi.org/10.1007/s41686-017-0005-1

Koyunlu-Unlu, Z., Dokme, I., & Unlu, V. (2016). Adaptation of the science, technology, engineering, and mathematics career interest survey (STEM-CIS) into Turkish. *Eurasian Journal of Educational Research, 63,* 21-36. http://dx.doi.org/10.14689/ejer.2016.63.2

Kurtulus, A., & Uygan, C. (2010). The Effects of google SketchUp based geometry activities and projects on spatial visualization ability of student mathematics teachers. *Procedia Social and Behavioral Sciences, 9,* 384-389. https://doi.org/10.1016/j.sbspro.2010.12.169

Lavonen, J., Gedrovics, J., Byman, R, Meisalo, V., Juuti, K., & Uitto, A. (2008). Students' motivational orientations and career choice in science and technology: A comparative investigation in Finland and Latvia. *Journal of Baltic Science Education, 7*(2), 86-102.

Lord, T. R. (1985). Enhancing the visuo-spatial aptitude of students. *Journal of Research in Science Teaching, 5*, 395-405. https://doi.org/10.1002/tea.3660220503

Luo, W., Wei, H.-R., Ritzhaupt, A. D., Huggins-Manley, A. C., & Gardner-McCune, C. (2019). Using the S-STEM survey to evaluate a middle school robotics learning environment: Validity evidence in a different context. *Journal of Science Education and Technology, 28*, 429-443. https://doi.org/10.1007/s10956-019-09773-z

Meyer, M., Cimpian, A., & Leslie, S. J. (2015). Women are underrepresented in fields where success is believed to require brilliance. *Frontiers in Psychology, 6,*235. https://doi.org/10.3389/fpsyg.2015.00235

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.

Miller, K., Sonnert, G., & Sadler. P. (2017). The influence of students' participation in stem competitions on their interest in STEM careers. *International Journal of Science Education Part B, 8*(2), 95-114.

Ministry of National Education (2018). *Turkish elementary science curriculum (Grades for 3-8).*Author. Retrieved on June 28, from http://mufredat.meb.gov.tr

Mohr-Schroeder, M. J., Jackson, C., Miller, M., Walcott, B., Little, D. L., Speler, L., Schooler, W., & Schroeder, D. C. (2014). Developing middle school students' interests in STEM via summer learning experiences: See blue STEM Camp. *School Science and Mathematics, 114*(6), 291-301. https://doi.org/10.1111/ssm.12079

Murdock, K. L. (2009). *Google SketchUp and SketchUp Pro 7 Bible.* Wiley.

Nadelson, L. S., & Seifert, A. L. (2017). Integrated STEM defined: Context, challenges, and the future. *The Journal of Educational Research, 110*(3), 221-223. https://doi.org/10.1080/00220671.2017.1289775

Nakiboglu, C. (2008). Using word associations for assessing non major science students' knowledge structure before and after general chemistry instruction: the case of atomic structure. *Chemistry Education Research and Practice, 9*, 309-322. https://doi.org/10.1039/B818466F

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

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states.* The National Academies Press.

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.
Pett, M. A. (1997). *Nonparametric statistics for health care research.* Sage.
Plant, A. E., Baylor, A. L., Doerr, C. E., & Rosenberg-Kima, R. B. (2009). Changing middle-school students' attitudes and performance regarding engineering with computer-based social models. *Computers and Education, 53*, 209-215. https://doi.org/10.1016/j.compedu.2009.01.013
Prokop, P., Prokop, M., & Tunnicliffe, S. D. (2007). Is biology boring? Student attitudes toward biology. *Journal of Biological Education, 42*(1), 36-39. https://doi.org/10.1080/00219266.2007.9656105
Rafi, A., Samsudin, K. A., & Said, C. S. (2008). Training in spatial visualization: the effects of training method and gender. *Educational Technology and Society, 11*(3), 127-140.
Sen, C., Ay, Z. S., & Kiray, S. A. (2021). Computational thinking skills of gifted and talented students in integrated STEM activities based on the engineering design process: The case of robotics and 3D robot modeling. *Thinking Skills and Creativity, 42*, 100931. https://doi.org/10.1016/j.tsc.2021.100931
Sha, L., Schunn, C., & Bathgate, M. (2015). Measuring choice to participate in optional science learning experiences during early adolescence. *Journal of Research in Science Teaching 52,* 686-709. https://doi.org./10.1002/tea.21210
Shavelson, R. J. (1972). Some aspects of the correspondence between content structure and cognitive structure in physics instruction. *Journal of Educational Psychology*, *63*, 225-234. https://doi.org/10.1037/h0032652
Stubbs, K., Casper, J., & Yanco, H. A. (2014). Designing evaluations for K-12 robotics education programs. In M. Khosrow-Pour (Ed.), *K-12 education: concepts, methodologies, tools, and applications* (pp. 1342-1364). IGI Global.
Tai, R., Liu, C., Maltese, A., & Fan, X. (2006). Planning early for careers in science. *Science, 312*(5777), 1143-1144. https://doi.org/10.1126/science.1128690
Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., Boeve-de Pauw, j., Dehaene, W., Deprez, J., De Cock, M., Hellinckx, L., Knipprath, H., Langie, G., Struyven, K., Van de Velde, D., Van Petegem, P., & Depaepe, F. (2018). Integrated STEM education: A systematic review of instructional practices in secondary education. *European Journal of STEM Education, 3*(1),1-12.
Wyss, V. L., Heulskamp, D., & Siebert, C. J. (2012). Increasing middle school student interest in stem careers with videos of scientists. *International Journal of Environmental and Science Education, 7*(4), 501-522. https://doi.org/10.20897/ejsteme/85525
Yan, J., Li, L., & Yin, J. (2020). Effects of MSTI summer camp program on studentsâ€™ perception on STEM learning. *Journal of STEM Education: Innovations and Research, 20*(2), 58-64.
Yuen, T., Boecking, M., Stone, J., Tiger, E. P., Gomez, A., Guillen, A., & Arreguin, A. (2014). Group tasks, activities, dynamics, and interactions in collaborative robotics projects with elementary and middle school children. *Journal of STEM Education, 15*(1), 39-45.
Zhong, B., Zheng, J., & Zhan, Z. (2020). An exploration of combining virtual and physical robots in robotics education. *Interactive Learning Environments*. https://doi.org/10.1080/10494820.2020.1786409

Appendix. Images for the steps of the P3 task taxonomy

Steps	*Activities*		
Practice	 Robotics & Coding	 Art & Design	 SketchUp
Problems	 Robotics & Coding		 SketchUp
Projects		 Mars Mission Projects	