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First-hand Experience with Engineering Design and Career Interest in Engineering: An Informal STEM Education Case Study

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Abstract

The purpose of this study is to present students' experiences, interest in engineering, and personal narratives while participating in a robotics summer camp in a metropolitan city in Turkey. In this study, I used qualitative data collection methods such as interviews, field notes, and observations. I used the four principles of Engle and Conant as a framework for analyzing their interactions and tasks as well as to make sense of their mutual interactions, tasks, and social structure in the robotics summer camp. The study findings indicated that the robotics summer camp was different from regular science classrooms in terms of goals, practical work, and social structure. The robotics summer camp provided students with the opportunity to engage in robotics activities and have personal interactions with engineering researchers about engineering and their future career plans. The robot design experience and close relationships with engineering professionals at the camp were sources that nurtured and maintained student interest in engineering. I concluded that the robotics summer camp was a venue for students to gain first-hand experiences, develop and sustain interest in engineering, and comprehend the nature of engineering in general. This in turn helped students to determine their career choice and sustain a lifelong interest in engineering.

Keywords: Engineering experience • Interest in engineering • Informal learning setting • Active engagement • Robotics activities • Career choice

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This study describes the characteristics of an informal learning setting where engineering design challenges were provided to high school students in a metropolitan city in Turkey. Active engagement in engineering design challenges has been presented as a means for students to foster their interest in engineering. The nature of a robotics summer camp was distinguished from a regular science classroom in terms of *goals*, *activities*, and *social structure,* indicating that students were provided with more first-hand engineering experiences which are not a part of conventional science classrooms. In this regard, the main objective of the study is not to argue that robotics summer camps outperform science classrooms. Instead, this study utilizes the nature of a regular science classroom to suggest designing a sound science learning environment that incorporates engineering tasks and designs.

School is accepted as a formal learning setting where students perform their social activities and make sense of their learning and understanding to seek ways of participating and being in the world (Verma, Puvirajah, & Webb, 2015). However, regular school environments discourage students from being more engaged and developing responsibility for their learning, which demotivates their understanding (Gardner, 1991). Additionally, learning is not limited to school activities, as individuals spend most of their time outside of the school environment (Bransford, Brown, & Cocking, 2000). Their learning mostly takes place away from school (Falk & Dierking, 2010). For this reason, I chose a robotics summer camp with no intention of replacing in-school activities with summer camp activities. This study can motivate one to seek how learning occurs in both learning settings and understand in what ways a sound learning environment can be designed within the context of science.

Informal learning takes place outside the school environment. Included among informal learning settings are science clubs, museums, zoos, planetariums, national parks, summer camps, and natural settings (Falk & Dierking, 2010; Simsek, 2011). Such settings allow individuals to perform activities and learn topics in the presence of a teacher or more experienced person within a flexible environment (Gerber, Marek, & Cavallo, 2001). In informal learning settings, individuals gain experiences which are "contextual, personal, relevant, collaborative, non-linear, and open-ended" (National Research Council [NRC], 2009; p. 11). Informal learning experiences have the potential to encourage individuals to make sense of societal issues; increase interest in science, technology, mathematics, and engineering; and support their curiosity and creativity in dealing with the challenges of everyday life (NRC, 2009). More specifically, informal learning experiences can support individuals in developing engineering problem-solving and design skills as they engage in engineering challenges. In turn, individuals can pursue a career in the fields of engineering (Apedoe, Reynolds, Ellefson, & Schunn, 2008; National Academy of Engineering and National Research Council, 2009; Sadler, Coyle, & Schwartz, 2000). Therefore, this study aims to highlight the importance of informal learning settings for individuals who are about to enter a university with the desire to pursue an engineering degree by eliciting the characteristics of a summer camp and the general picture of a science classroom.

Science, technology, engineering, and mathematics (STEM) education has gained more attention in the US and EU countries over the last decade. Many states in the US have started to use Next Generation Science Standards [NGSS] in classes (NGSS Lead States, 2013). NGSS provides a framework where engineering and science standards are integrated so students can experience engineering design challenges with scientific content. The main idea behind this can be related to STEM programs having less of an emphasis on engineering. To deal with less emphasis on engineering, K-12 students engage themselves in the nature of engineering and engineering-design challenges through informal learning programs (Apedoe et al., 2008; Cunningham, Knight, Carlsen, & Kelly, 2007; Yilmaz, Ren, Custer, & Coleman, 2010). However, very limited efforts have been made to draw attention to K-12 engineering education in a Turkish context (Cavas et al., 2012; Marulcu & Sungur, 2012). In this study, I explored a robotics summer camp through which high school students were engaged with engineering-design challenges, highlighting that the robotics summer camp is a platform for fostering interest in engineering and showing that summer camps are distinct from regular science classrooms in regard to goals, practical work, and social structure. Additionally, I indicated that resources for interest throughout the camp were a means for individuals to determine engineering as a career choice. Thus, the study findings can help STEM educators, learning scientists, and curriculum designers to develop a sound learning environment in the context of schools so as to sustain individual interest in engineering.

Problem

Engineering is relatively popular and appealing among different professional fields in Turkey due to its highly technical and economic dimensions

(Caner & Okten, 2010; Kuzgun, 2003). Its popularity has been supported by the OSYM (Ölçme, Seçme ve Yerleştirme Merkezi, 2013) national report. According to this report, 380,540 individuals were admitted to Turkish universities and of these, 80,037 chose technical sciences (mainly engineering-related areas such as mechanical, chemical, civil, petroleum, and computer engineering) as a field of study for their post-secondary education. At the same time, 14,033 individuals selected mathematics and natural sciences, and 7,941 individuals selected agriculture and forestry as their field of study. Furthermore, new admissions to engineering departments in universities have increased from 24,964 in 1999 to 80,037 in 2013. These numbers support the notion that engineering is a preferred career area among young individuals in comparison to other professional fields.

On the contrary, OSYM findings indicate that the number of graduates in engineering is disproportionate to the number of new admissions. For example, 36,786 students (11,738 females and 25,048 males) graduated from programs in the technical sciences, whereas 80,037 students (25,833 females and 54,204 males) were newly admitted to technical science programs in 2012; for 2011, there were 31,861 (9,181 female and 22,680 male) graduates and 68,347 (21,274 female and 47,073 male) new admissions; and in 2010 there were 30,018 (7,883 female and 22,135 male) graduates and 63,963 (19,757 female and 44,206 male) new admissions (OSYM, 2011, 2012). These numbers reveal that less than half of newly admitted students graduate from engineering-related programs. In that regard, Abdullah, Yalçın, Bayrak, Sazak, and Yıldız (2006) and Cakir and Yelmen (2011) have drawn our attention to the quality, purpose, and mission of engineering education programs. A more theoretical background with less practical experience is provided to candidate engineers throughout their four-year higher education (Akgul, Ucar, Ozturk, & Eksi, 2013).

To some extent, OSYM's findings alert us to an issue of why engineering graduates are less in number compared to the young Turkish students who choose engineering as their career. I can associate this alert with three problems: (1) *lack of engineering practice in K-12 Turkish curricula*, (2) *the nature of counseling and consultation services in schools*, and (3) *societal perceptions of engineering*. First, the curriculum objectives for grades K-12 often do not incorporate engineering tasks or design activities which utilize the most recent technology (Alexander, 2000). Instead, the focus is more on preparing students for the nation-wide university entrance exam by heavily teaching content knowledge for science and mathematics (Corlu, Capraro, & Capraro, 2014). Students who want to pursue a career in engineering or the physical sciences take some parts of the university entrance exam constructed through content knowledge and skills in science, mathematics, and literature (Elliot, 1996). Students choose engineering as their career choice without experiencing the nature of engineering work throughout their schooling. More explicit is the notion in Turkish society that students with strong science and mathematics content knowledge can pursue a degree in science and engineering. Therefore, experience with engineering work and its challenges have been ignored in the school setting. Secondly, school counseling and consultation services are a means for students to learn about universities and programs, but these services are limited to lectures, university trips, workshops, and so on (Akkok & Watts, 2003). In other words, such services are oriented towards the university entrance exam without considering the students' performance or background in high school (Elliot, 1996). Prominently, it is not in the make-up of these services to allow students to explore the nature of engineering or interact with engineering scientists and researchers in order to experience how they work to generate solutions to problems. Thirdly, schools, parents, and stakeholders expect students to choose engineering as career choice due to its highly technical and economical dimensions (Kuzgun, 2003). In that regard, there is a belief that completing engineering programs will open a door for individuals to find a job with a high salary after graduating (Caner & Okten, 2010). As a result, the disproportionate ratio between new admissions and graduates in engineering programs appears to be related to three problems: a lack of experience in engineering practice, the nature of school counseling and consultation services, and the perception of engineering in society.

Moreover, I anticipate that these three problems are associated with the resources for individual motivation. Motivational resources can be classified as *extrinsic* or *intrinsic motivation* (Bathgate, Schunn, & Correnti, 2014; Hidi, Renninger, & Krapp, 2004; Katz, Assor, Kanat-Maymon, & Bereby-Meyer, 2006). Extrinsic motivational resources include the popularity of engineering, its job security, and its economic benefits. These resources can be a means for individuals to choose engineering as a career. Intrinsic motivational resources can be related to a desire, passion, intention, or interest in engineering. This interest in engineering can be developed through first-hand engineering experiences. A lack of such experience can result in a lack of intrinsic motivation. Although extrinsic motivational resources enable individuals to choose engineering as a career choice, individuals may not continue to be personally interested in engineering (Boe, 2012). This is because they lack the intrinsic motivation which stems from the desire or willingness to practice engineering. In line with Katz et al.'s study (2006), individuals have more motivation if they develop a high level of interest through situational experience with a task or topic (Hidi & Renninger, 2006; Hidi et al., 2004). In addition, interest is closely related to intrinsic motivation within the context of self-determination theory. Self-determination theory delineates the relation between a person and activity in such a way that individuals without any desire or need do not necessarily have interest in related activities. (Deci, 1992). While extrinsic motivational resources can regulate an individual's career choice in engineering externally with less autonomy, intrinsic motivational resources do so internally with more autonomy. Such autonomy allows individuals to be more engaged in an interesting task (Ryan & Deci, 2000). In this regard, the disproportionality between new admissions and graduates in engineering programs can be associated with whether or not an individual has experienced engineering practices and has been intrinsically motivated to perform engineering activities prior to higher education. Therefore, this study aims to highlight the importance of an informal learning setting for individuals who are about to enter a university with a desire to pursue an engineering degree through first-hand experience with engineering tasks in a robotics summer camp prior to starting their higher education.

Study Purpose

In this study, I describe a robotics summer camp where students were actively engaged with engineering design challenges. I explore to what extent robotics activities fostered student interest in engineering. A team of scholars from a private college in Turkey provided the informal learning opportunities for high school students. The high school students were encouraged to work with electronics and electrical and mechanical objects to complete a series of robotics activities. Student participants were informed about various engineering fields as career options through faculty presentations, personal talks, and robot design activities. Thus, this study aims to present the students' experiences, interest in engineering, and personal narratives to highlight the importance of an informal learning setting for individuals who are about to enter a university with the desire to pursue an engineering degree. The research questions of the study are as follows:

1. What are the characteristics of the robotics summer camp?
2. How do the robotics summer camp activities differ from regular science activities in school?
3. To what extent does the robotics summer camp support student interest in engineering?

Conceptual Framework

Interest in Engineering

Interest is concerned with affect, knowledge, and value; it includes both affective and cognitive components which have biological roots (Hidi & Renninger, 2006; Hidi et al., 2004). Interest is grounded in the interaction of a person with a particular content. The content that the person is engaged in and the environment in which the person is involved define the person's interest and contribute to its development. In this regard, Hidi and Renninger (2006) introduced a four-phase model of interest development as they extended two forms of interest (situational and individual) as specified by Krapp, Hidi, and Renninger (1992). The development of a person's interest can be supported by external factors such as project-based learning, cooperative group work environments, or by the challenges a person confronts in a given task that lead to understanding knowledge (Hidi & Renninger, 2006).

Situational interest is important in attracting students' attention to engineering, and this interest emerges at an early age. Studies have shown that early interest unexpectedly decreases as students grow and advance to higher levels in school (Osborne, Simon, & Collins, 2003; Zimmerman, 2012). In other words, a transition from situational interest to individual interest may not occur as teachers and parents expect. Therefore, both situational and individual interests are significant considerations for curriculum developers, learning scientists, and educators in terms of nurturing young individuals' interest in pursuing a career in engineering (Brown & Krane, 2000; Dabney et al., 2012; Lent, 2000). This study explores the extent to which a robotics summer camp is a means for students to trigger, nurture, and sustain their interest in engineering.

Self-Determination Theory

In self-determination theory, individuals are considered to be intrinsically motivated when they intentionally do what interests them. Self-determination theory describes and explains the individual's interest in an activity or task when the needs, desires, or intentions of the self harmonize with an activity (Deci, 1992). Additionally, self-determination theory explains interest within the context of an individual's psychological needs: the needs for competence, autonomy, and relatedness in social contexts. These three needs bolster intrinsic motivation (Ryan & Deci, 2000). More specifically, Deci, Vallerand, Pelletier, and Ryan (1991) defined these innate needs as follows: (1) Autonomy refers to the self-determination of one's own actions. Individuals have the ability to initiate and regulate their own actions. Intrinsic motivation can increase when individuals are held accountable for their task (Hagay & Baram-Tsabari, 2015). (2) Competence indicates the ability of individuals to perform basic actions. Individuals with a sense of success and satisfaction are motivated to determine their own actions. (3) Relatedness involves developing secure and satisfying social connections with others in a social context. Social connections among individuals in a social context enhance solidarity. Deci et al. (1991) presented three possible conditions that support an individual's self-determination within the context of *valuing*. Individuals value an activity or a task internally when (1) they feel aware of the personal utility of an activity; (2) they are given choices about an activity; (3) they feel their perspectives have been acknowledged. Therefore, valuing emerges if individuals feel autonomous, competent, and related throughout their activities.

Informal Learning Programs in Engineering

Informal learning programs in engineering are a means of attracting the attention of K-12 students and increasing their interest in engineering. When students are actively engaged with engineering practices, they develop a higher interest in engineering (Cavas et al., 2012; Salamon, Kupersmith, & Houstenno, 2008; Weinberg et al., 2001; Yilmaz et al., 2010). For example, a group of engineering faculty developed a summer camp program for high school students in the US (Yilmaz et al., 2010). This program included hands-on, competition-oriented projects in electrical, environmental, mechanical, civil, and chemical engineering. The purpose of the camp program was to encourage the participants to acquire STEM subjects and to motivate them to continue engineering in higher education. Throughout the one-week camp program, thirty students were engaged in projects associated with real-world problems such as air pollution, nanoparticles, and desalination. The findings from the study demonstrated that students had developed positive feelings toward engineering as they gained real-world experiences.

Salamon et al. (2008) designed a program for middle school students in the US to engage students with LEGO Mindstorms NXT robotics kits. The program consisted of lessons and competitive events during which the students faced various design challenges. The students worked in teams of four or five to experiment with the LEGO kits, programming to find solutions for the given challenges. The findings indicated that the program served as a platform to engage students in STEM activities and helped them develop an interest in STEM careers.

A similar program was designed using four-day LEGO courses (Weinberg et al., 2001). The courses included the introduction of the LEGO kits and LEGO programming, as well as the use of the Robolab visual programming language. These courses were structured to enhance student engagement in robotics competitions. During the courses, the students were introduced to and interacted with a social robot. The study findings indicated that students' learning experiences with robotics activities bolstered their interest in studying engineering.

Moreover, another group of researchers worked with 23 students aged 12-13 (Cavas et al., 2012). The students were engaged with robotics activities using LEGO Mindstorms NXT 2.0. The students were taught to recognize a robot and its parts, work with sensors, understand basic programming, and use a robot to find solutions for certain socio-scientific issues. The findings indicated that robotics activities provided a means of increasing student interest in STEM fields.

Bruder and Wedeward (2003) discussed an outreach program for integrating robotics into secondary education, aiming to engage students with engineering tasks. They invited a group of students to spend a day watching how engineering students worked and operated their designs at New Mexico Tech. Students experienced a mobile robot kit with a set of features such as the 16-b Motorola HC12 microcontroller, a powerful 12-V lead-acid battery, and three infrared proximity sensors. Bruder and Wedeward observed that outreach programs through robotics activities played an important role in encouraging students to explore the nature of engineering.

Slangen, van Keulen, and Gravemeijer (2011) investigated the extent to which students learn when working with robots. They used LEGO Mindstorms NXT robotics kits to explore students' reasoning patterns and conceptual understanding. They basically designed robotic direct manipulation of the environment as a learning context. In this context, students were exposed to higher-order thinking activities in order to understand how they could conceptualize the nature of robots and robots as integrated systems. In other words, Slangen et al. desired to explore whether or not to develop technological literacy through robotics activities when students were engaged in an environment of direct manipulation. They found that students developed more sophisticated conceptual perspectives on robotics.

In summary, various programs involving robotics activities were aimed at drawing student attention to STEM fields, motivating them to pursue STEM careers, and introducing them to interdisciplinary concepts. More importantly, they revealed that active engagement in engineering practices was the key to fostering interest in engineering, in turn pursuing a career in engineering. Likewise, in the present study, I investigated a robotics summer camp offered at a private university to energize student interest in engineering and stimulate them to choose engineering as their career. As a few students had had prior experience with science and engineering activities in informal learning contexts (competitions, science fairs, extra-curricular clubs), I aimed to explore different resources to encourage their interest in engineering.

The robotics summer camp that I studied was very different from other programs students often have engaged in in Turkey. University supported programs in Turkey simply introduce the university culture and environment to K-12 students. Students visit universities to learn about engineering programs and future career fields through lectures and workshops. The summer camp that I described in this study actively engaged students in engineering design, challenging and providing first-hand experience with engineering tasks. Moreover, the robotics summer camp I studied here differs from others described in the literature (Barker & Ansorge, 2007; Sullivan, 2008) in the sense that the students utilized actual mechanical, electrical, and electronics tools to make robots, rather than using LEGO kits.

Robotics Competitions and Science Classrooms

The robotics summer camp I studied here was simply based upon a competition. Student groups were expected to compete with each other in order to obtain a scholarship for higher education. They had come to the camp with this expectation. To explore and distinguish between the characteristics of a summer camp environment and a science classroom environment, I draw upon the framework of four principles: (1) *problematizing content*; (2) *giving students authority*; (3) *holding students accountable to others and to disciplinary norms*; and (4) *providing relevant resources* (Engle & Conant, 2002). These four principles are a means for students to become productively engaged in activities. The principle of problematizing content refers to opportunities for encouraging students to generate questions, proposals, and challenges in order to make sense of concepts, rather than assimilating concepts and facts. The principle of giving students authority addresses students' use of authority for performing their own activities. In most science classrooms, teachers are given the role of organizing class activities, and students are expected to follow rules in order to learn and succeed (Roth, 2000). In robotics competitions, teachers and students appeared to take on different roles in organizing activities, as the teachers shared their authority and power of knowledge with their students. Holding students accountable to others and to disciplinary norms means that no member of a group is dominant. Instead, each member is given responsibility for performing activities. Providing relevant resources refers to providing the materials and access to information that foster student engagement. While robotics competitions provide students with the time and necessary materials to reach their goals, students in science classrooms may not be allowed such an opportunity because they have to follow the curriculum objectives as their goal with limited resources within a specified time frame.

Applying these four principles can be a means of establishing collaboration, sharing, and solidarity among the individuals in a social context (Amey & Brown, 2004; Verma et al., 2015) and provide understanding of how summer camps are different from formal learning environments including the role of the teacher or authority that judges student ability. Giving students authority, control, and accountability is critical because they will have more autonomy to engage in activities they conduct with these feelings (Ayar, Aydeniz, & Yalvac, 2015). In this study, I uncover the critical elements of the robotics summer camp that nurtured and sustained student interest in engineering.

Methods

The main purpose of this qualitative study is not to generalize the study findings by eliciting, explaining and distinguishing summer camp and school science activities. Instead, it aims to highlight the potential characteristics of summer camp and school science activities in order to contribute to the effort of designing a sound learning environment in the context of school. In doing so, I was aware of the social and educational backgrounds of students, teacher quality, and physical environment in the context of school. However, the purpose of the study is to present students' experiences in both learning settings, understand how students are engaged with hands-on and minds-on activities, and explore the ways in which first-hand engineering experiences contribute to student learning and engineering performance without any generalizations. Below, as methodologically defined in Creswell (2013), I described the context and content of the robotics summer camp, defined the people (organization team, students, and researcher) as participants, explained data collection and analysis methods, and interpreted data as per a qualitative study. At the same time, I have done this without defining a control group or generalizing the data because qualitative studies do not include control groups or make generalizations. In other words, my main purpose was to answer research questions from a qualitative perspective.

Context and Content of the Robotics Summer Camp

The 12-day robotics camp offered lectures by engineering researchers and faculty members during the summer of 2012 (Table 1). Participating students were exposed to some background information about engineering through the lectures. The lectures were presented through (a) a computer programming course (6 hrs.), (b) a basic electrical-electronics course (4 hrs.), (c) a Proteus/PIC/MicroC training course (5 hrs.), and (d) electronics applications (printed circuit boards (PCB) and their production (4 hrs.). While a faculty member taught the programming course, graduate students taught the other courses with faculty members taking on secondary roles, stepping in when they noticed a point being missed during the lectures. After the participants learned some background information on engineering, they engaged in practical activities (brazing things on PCB's) to begin making their own robots. They were given some tasks, such as transferring a circuit to a breadboard; transferring a circuit to a breadboard with LEDs; and testing a CNY70 sensor on the breadboard. They studied a DC motor, a 7895 regulator, a PIC 16F628A microcontroller, integration of the L298 dual full bridge driver, and the LM 324 operational amplifier (updated).

Students were encouraged to attend presentations and talks given by visiting faculty members and graduate students. During these presentations, they listened to narratives from engineering professionals on how they had become engineering researchers. The visiting graduate students shared their experiences in engineering and talked about where they were currently and where they wanted to go next. Introducing the visiting faculty members and the graduate students to the camp participants was essential in helping them to envision their near future should they choose engineering as a career. In addition, the faculty members talked about their research. For instance, one faculty member presented his doctoral study, where he had designed a robot that could be used in cardiovascular surgery. Another faculty member talked about the process of designing and making a robot that mimics humans.

In addition, the participating students were engaged in designing, building, testing, and modifying their robots through practical implementations. They were informed daily as to what and where they would do practical work for observing whether their robot worked as expected. They were given a challenge to make a robot that could work on race course 1 (Figure 1). If they passed the challenge on course 1, two more challenges would be given; namely, to pass course 2 (Figure 2) and course 3 (Figure 3) respectively. If they did not fail in these challenges, they were expected to compete on the fourth course (Figure 4). Winning this final race would earn them a scholarship for higher education.

As an extracurricular activity, participating students visited a private company where passenger cars and other vehicles were manufactured and exported to various countries. During this trip, the students saw where and how robots were used for automobile production. At the same time, they witnessed a workplace where engineers could be employed after graduation.

Figure 1

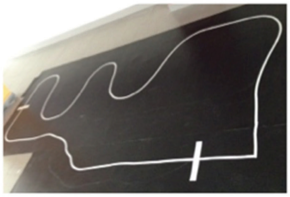

Figure 2

Figure 3

Figure 4

Table 1
The Robotics Summer Camp Program

	9:00-9:10	9:10-9:25	9:25-9:45	9:45-10:45	10:45-12:00	12:00-12:30	12:30-13:30	13:30-14:30	14:30-15:15	15:15-18:30	18:30-19:30	19:30-21:00
Day 1	Dean's Speech	Team Leader's Speech	Student Orientation	Robotics and NAO Robots Presentation	A Faculty's Presentation	Ice Breaker	Lunch	A Faculty's Presentation	Robot Demos	Programming	Dinner	
Day 2	Programming						Lunch	A Faculty's Presentation	Basic Electronic Education		Dinner	
Day 3	Proteus/PIC/MicroC Education						Lunch	Proteus/PIC/MicroC Education		A Faculty's presentation	Dinner	
Day 4	Printed Circuit Board and its Production						Lunch	Knight Rider on Printed Circuit Board	A Faculty's Presentation	Begin Making a Robot: Brazing Things on Board	Dinner	Free Study
Day 5	A Faculty's presentation						Lunch	Make a Robot			Dinner	
Day 6	Trip to Ford Company							City Sightseeing-Istanbul			Dinner	
Day 7	Practice in Race Course 1 (Short)						Lunch	Practice in Race Course 1 (Short)			Dinner	Race in Race Course 1
Day 8	Practice in Race Course 2 (Long) (Tricks and Details)					A Faculty's Presentation	Lunch	Practice in Race Course 2 (Long)			Dinner	
Day 9	Practice in Race Course 2 (Long)						Lunch	Competition in Race Course 2 (Long)			Dinner	
Day 10	Practice in Race Course 3						Lunch	Competition in Race Course 3			Dinner	
Day 11	Practice in Race Course 4 (Final Version)						Lunch	Practice in Race Course 4 (Final Version)			Dinner	Practice in Race Course 4 (Final Version)
Day 12	Practice in Race Course 4 (Final Version)						Lunch	Final Race; Dean's speech	Vision speech	Ford Company Representatives' Speech; A Faculty in Japan Speech	Winners Ceremony	

Participants

Organization Team: The robotics summer camp was designed by a team of engineering faculty members and university students. There were four engineering faculty members. One was the leader of the organization team, and his research was in electrical-electronics engineering. The second faculty member, whose research was in robotic surgery, was in the mechanical engineering department. The third faculty member, whose research was in software engineering, was in the department of computer engineering. The fourth faculty member, whose research was in medical robotics, was in the department of computer engineering. There were five undergraduate students in the department of electrical-electronics engineering, and one undergraduate student in the computer-engineering department. There were three graduate students pursuing a master's degree and one pursuing a doctorate in engineering.

Students: A total of 145 students from 34 cities across Turkey completed an online questionnaire (including demographic information, engineering content, and programming language) before the camp and wrote a personal essay explaining why they were interested in participating in the robotics summer camp. The organization team members interviewed students who had completed these two activities. These interviews were for eliminating them on the basis of their interest in the robotics camp and a career in engineering.

Finally, students (N=27; 4 females, 23 males) were chosen to join the camp based upon their responses to the interview questions, scores in engineering-content knowledge from the questionnaire, and essays. The gender difference, which was unexpected, was naturally associated with the student responses received during the application. Seventeen students had already graduated from high school, taken the university entrance exam, and were waiting for their scores which would allow them to select their major to pursue in a university. Ten students were senior high school students who would take the exam a year later. Out of the 27 students in this study, thirteen students were from public *Anatolian High Schools*. Seven students were from public *Science High Schools* and one from a private *Science High School*, where students have considerable aptitude in science and mathematics subjects. One student was from a public Anatolian technical high school and one from an unspecified technical high school, where subject matter and technical skills are introduced and taught. One student was from an unspecified public high school, one from a private international high school, and one from a private minority high school. Their demographics are illustrated in Table 2.

Table 2
Participants by student number, school classification, and school type

Name	School Classification	School Type
Student 1, 3, 4, 7, 8, 9, 11 , 12, 13, 18, 19, 22, 24	Anatolian High School	Public
Student 5, 6, 10, 16, 20, 23, 26	Science High School	Public
Student 2,	Anatolian Technical High School	Public
Student 27	Technical High School	Public
Student 17	International High School	Private
Student 14	Science High School	Private
Student 15	Minority High School	Private

Researcher: The researcher's interest is in STEM education and learning environment design. He had not had any experience with robotics activities. He observed the organization team and study participants for 12 days. Throughout his observations, he established the balance between being an observer and becoming a part of the group in order to obtain the participants' feelings, thoughts and views as well as to capture the problems and difficulties encountered by the participants. At the beginning, he just observed activities, interactions, and social structure at the camp. Then his participation level slightly increased over time as he began asking questions to students and the organization team involved in the groups. Therefore, he located his position as a participant-observer.

Data Collection and Analysis

In this study, I collected data through interviews, field notes, and observations throughout the 12-day camp. I conducted interviews with 27 students. I interviewed twenty-four students in pairs and three students individually. Each interview took 35-60 minutes. I took field notes as the participants received instruction on theoretical knowledge, engaged in practical work to make their own robots, and competed with others to win the final race. I took field notes when the invited speakers talked about their research. I observed the students for 12 days as they worked at the electrical-electronics laboratory, testing and re-designing their robot models on four race courses. My observations allowed me to identify student-student, student-faculty, and student-mentor interactions. These interactions were a means for me to understand how robot models were developed and tested through an iterative process.

Additionally, during these observations, I used Engle and Conant's four principles as a framework (problematizing content, giving authority to students, holding students accountable to others and to disciplinary norms, and providing relevant resources) for analyzing their interactions and tasks. *Problematizing content* refers to the opportunity to encourage students to generate questions, proposals, and challenges in order to make sense of concepts, rather than assimilating concepts and facts. For example, faculty problematized engineering tasks in such a way that they changed the rules (the number of sensors on the vehicle, violations) as students prepared their own vehicle for a race course. The principle of *giving students authority* addresses student use of authority for performing their own activities. For instance, because student groups were designed to work together, they were given authority to complete their own tasks. They were provided with an opportunity to name their group, design their own vehicle using their creativity and skills, and were encouraged to build whatever they liked. *Holding students accountable to others and to disciplinary norms* means that no member of a group was dominant; instead, each member was given the responsibility of performing activities. In that regard, students were committed to performing their engineering activities of designing, building, testing, retesting, and redesigning their vehicle for the final race. Intrinsically, they felt accountable for completing tasks without any oppression from another member. They believed that as a group they would get the chance to enter the final race. *Providing relevant resources* refers to providing materials and access to information that fosters student engagement. In this sense, each group was provided with relevant materials at the electrical-electronics laboratory where they worked to build their vehicle. It was filled with equipment and materials ready for use in designing and building one's own vehicle. This framework helped me understand the extent to which robotics activities provided a means for active student engagement, which in turn fostered their interest in engineering. In other words, using such a framework was a way for me to make sense of the mutual interactions, tasks, and social structure in the robotics summer camp.

I transcribed the interviews verbatim and analyzed them using the constant comparative method along with open coding, axial coding, and selective coding (Glaser & Strauss, 1967). In this process, while considering a framework grounded on interest, an informal setting, and Engle and Conant's four principles, I portrayed robotics and school activities in regard to *goals*, *practical work*, and *social structure*. The goals were differentiated between camp and school settings; in school settings, learning was focused on developing content knowledge in science and mathematics in preparation for the nation-wide standardized exam, whereas experiencing engineering tasks through designing robots was the goal of the robotics camp. This difference defined the content of daily activities, as school settings aim at less practicality and less interaction than the camp setting did. In regard to the social structure of both settings, the camp was based more on collaboration, sharing, and solidarity, while individualized learning and teacher authority dominate in the school setting. School objectives require individuals to increase their exam readiness by focusing more on content knowledge and test skills, while the camp objectives engaged the students in first-hand experience with engineering tasks which were more interesting to the students, who were about to determine their career choice in engineering for higher education.

To establish trustworthiness of the study, I used in-depth and detailed descriptions of my observations and field notes during the camp program. These observations focus on the mutual interactions between students and organizers, as well as among the student pair groups. Field notes were taken every day during the camp program, including when theoretical knowledge was presented and practical tasks were being performed. I triangulated the findings from the interviews with the field notes and observations (Creswell, 2013). Then, I established dependability using peer debriefing to control the collected data and findings. A learning scientist with a PhD in Curriculum and Instruction with specialization in STEM education was invited to the peer debriefing sessions (Lincoln & Guba, 1985). These sessions consisted of conversations and question-answer periods. She evaluated the purpose of the study, research questions, and findings concerning how well the data supported them. She was selected for peer briefing because she was familiar with robotics activities and had experience with qualitative research.

Findings

Robotics Summer Camp as an Alternative to the Traditional Science Classroom

The findings indicate that the robotics summer camp was distinct from the traditional science classroom in terms of *goals*, *practical work*, and *social structure*. The participants' goals at school consisted mainly of learning content-knowledge in science, mathematics, and other subjects in order to succeed on the nation-wide university entrance exam. These goals were to promote memorization, exam-oriented teaching, and exam preparation. Although most of the camp participants had attended *Science High Schools* and *Anatolian High Schools*, where hands-on and minds-on activities were often provided and where they were encouraged to work in science laboratories, the students had been more frequently exposed to content knowledge represented in their textbooks, tending to memorize that knowledge rather than face challenges. Due to the strong accountability measures reflected through the national exams, these students had generally been directed to familiarize themselves with the exam questions and techniques in order to bolster their exam readiness through memorization of the textbooks and mastery in the use of theoretical knowledge mainly presented in formulas and equations. This single goal of succeeding on the university entrance exam demanded less practical work and less interaction. In this regard, Student 8 found the textbooks problematic, noting that:

> "For instance, when you open the physics textbooks, you see lots of information, and there are many things to cover. In addition, you have to deal with memorizing and learning many formulas. These are all about education based on memorization. I don't think it's good for [formal] education."

The textbooks were also the staple material used for occasional laboratory activities. Student 9 explained that when they did laboratory activities, they often did "simple things that are in the textbooks." It seems that textbooks were the main source for structuring both classroom and laboratory activities in the participants' physics and chemistry classes. These textbook-based learning experiences are defined as an abstract means for students to make sense of physics and chemistry concepts, as textbook-based methods mainly favor rote memorization of concepts and methods for applying formulas. Student 9 additionally criticized this type of science learning as not only limiting the learning process, but also contradicting the university exams. As he explained:

> "The science activities provided to us are limited to the content of textbooks. I would criticize our education system here, because when you take the university entrance exam, you are expected to solve a question in a minute, and that determines your future. I am not sure how this system helps me in my life."

The nature of laboratory activities was also criticized by the students because these textbook-based, cookbook-style activities were mainly utilized either for practicing what was learned in the classroom or for grading purposes. Furthermore, the students found these activities to be relatively dull, providing only limited opportunities for them to use their imagination and creativity. For instance, Student 10 specifically explained, "Our physics teacher requires us to perform a project or an experiment through which we are graded. The experiment I conducted was similar to what was represented in our textbook. No imagination or creativity at all!"

Another student explained that their teachers were good at teaching them the science content using worksheets and practice exams from the textbook. For this student, however, these preparatory works were designed and used to prepare students to perform well on the university entrance exam. It seems that accountability measures dominated the decisions of teachers when deciding what or how to teach in their classrooms. Student 23 described the situation as follows, "I view our school as a *dershane* (a tutoring center) because our teachers use worksheets and exams to prepare us for the university entrance exam." The university entrance exam also impacts regular school scheduling as well. As this student further noted "Sometimes, music and art courses are replaced with mathematics and science courses to provide us with problem-solving sessions. The use of laboratories to do experiments is very limited because our school is exam-centered." Thus, the ultimate goal for the regular schools of the participating students was to prepare them for the university entrance exam. In turn, this impacted not only the teachers' regular classroom applications, but also the entire school curricula.

As opposed to the goals of their school settings, the participating students expected to gain experience with engineering work and explore the nature of various engineering fields for determining their career choice during the robotics summer camp. Such goals were established through practical tasks at the camp, which differentiated the robotics summer camp from regular science classrooms. For example, Student 1 found this summer camp "…more satisfying than what we had learned in school, because we were engaged in activities." This student additionally indicated that they had had more opportunity to do practical work and test the theoretical information that they had been given during the robotics summer camp. Student 3 specified the features of the program compared to regular school activities in detail:

> "You see observable results here, but at school you are always busy with other mathematics, not physics. The teacher asks a question, gives some numbers, and when I ask what the meaning of these numbers is, I'm simply told 'force.' What is 10-N force? How do you define 10-N force? I keep asking these questions, and then I'm told I am too interested in details. Here, we focused on the details. Let's say your car speed is 10 m/s or 9 m/s. We observed this here directly. In school, that is an abstract; here, it is concrete. This is the big difference."

As described by the students above, the students were observed during the summer camp to be provided with the opportunity to perform hands-on and minds-on activities through which they tested their theoretical knowledge and gained experience with robotics activities. They were involved in an iterative process that included designing robot models, testing them, re-designing them, and retesting them. This iterative process encouraged them to think critically and analytically, and to find the best solutions for dealing with the challenges given by the organization team. A description of such a procedure is noted by Student 14:

> "We encountered many problems as we designed our robot model. For instance, we had resetting and balancing problems. We dealt with such problems by doing a series of tests. We generated logic, though. Within that logic, we tested our robot model to see how it worked in different

situations. For example, when we situated the front tire, the robot turned the corner slowly. We changed its position and put it at the back, it then took the corners very quickly."

Similarly, Student 27 reported that in his group, they tried to find the best gravitational center and decided which sensor distance would be best for their robot model. In that regard, they asked many questions to find the solution. As he explained:

"We thought about where to put the batteries and motor on the robot model. We questioned what would happen if we put wheeled motors under the model. We tested it and observed that it did not work. Then we switched its position."

These findings revealed that the students had different sets of goals that drove different types of practices. In regular classrooms, the goals drove them towards memorization, preparation for the nation-wide exam, and limited interaction; while the goals of the camp prompted greater interaction and practical work.

The social structure of the robotics summer camp was grounded on *collaboration*, *sharing*, and *solidarity*. Most of the students worked in pairs, requesting help from their mentors, faculty members, and other pair groups when they met a challenge or could not find a solution to the challenge. A lower level-of-knowledge authority between the camp participants and the organization team members encouraged them to collaborate and develop mutual interactions to make progress in the iterative design process. Student 5 stated that while each group was working on their own projects, they did not compete with each other. The student noted that he had a good relationship with his group members, as well as the other group members. Rather than competing against other groups, "When one group passed the challenge, they then shared what they did and the method they used with the other groups."

Explaining the nature of collaboration and solidarity during this summer camp, Student 26 mentioned that:

"We felt there would be competition for the university scholarship. Yet from the beginning, we worked in pairs, asking each other how to use the materials and equipment and design the robot; we shared our knowledge and understanding within the pairs and with other groups. I mean, there was no competition at all. We realized at the end that our designs for the robots were similar. This showed that we worked together, and collaboration among individuals was very evident, although the pair groups had already been set."

The student groups were set to prepare for the final race, but they never felt that they had to compete with one another for the scholarship. Instead, they helped each other solve problems as they occurred. A learning environment offering flexibility and collaboration at the camp played a key role in establishing camaraderie among the camp participants. For Student 4, this was contrary to the individualized and competition-based learning environment at school. She expressed, "I did not see any such competition. Instead, we developed friendships, even though we come from different schools at different locations across the country. We talked about ourselves, our schools, and our future plans after high school."

Confirming the previous student's thoughts, Student 5 noted that he and his teammate worked with other group members overnight to solve challenges. He described the atmosphere at the camp as "warm enough to develop friendships with the other participants and even with the undergraduate students." Student 12 exemplified how this friendship and collaboration played a role in completing their projects during the summer camp:

"We felt a sense of friendship as we engaged with the robot design tasks. One of my friends helped me understand programming; the other solved a problem I had encountered. In a similar way, I did so as well. I solved simple coding problems by myself, and I asked for help from someone else with more experience and knowledge to deal with other problems, such as errors in electrical circuits."

Clearly, there was a strong sense of friendship and cooperation among the individuals, which was an atmosphere that many students indicated they had not found in their formal school settings. The following quotation illustrates this situation:

"[In school] our teachers do not trust us. They think that we would break laboratory equipment and harm lab materials. However, we can build a circuit and rebuild it. We need someone who will trust us. I believe in myself when it comes to physics. I can solve a problem. I can do anything you can think of! That's why the camp was advantageous for me."

In sum, the study findings indicated that the robotics summer camp was different from regular science classrooms in terms of *goals*, *practical work*, and *social structure*. While the goal of the classroom was limited to succeeding on the university entrance exam, the goals at the camp were to gain experience with designing a robot and to become familiar with engineering as the students prepared for the competition. The students were more engaged with theoretical content knowledge and less hands-on activities in the classroom, while the robotics summer camp offered more hands-on and minds-on activities and theoretical content knowledge as needed to solve their problem. The social structure in formal classrooms is grounded on the teacher's knowledge authority and individualized learning geared to the exam, whereas *collaboration*, *sharing*, and *solidarity* were the primary elements of the social structure within the context of the robotics summer camp. Thus, the robotics summer camp had the potential to make students more autonomous, competent, and related as they engaged with engineering activities.

Resources for Determining Engineering as a Career Choice

The set of data that emerged from the observations, field notes, and interviews indicated that there were some resources for students to use for determining whether or not to pursue engineering as a career choice. With the reality that some students had come to the robotics summer camp with engineering experience and background, I identified several resources such as *informal engineering experience*, *informal, unstructured engineering experiences*, *media*, *close relationship with an engineering professional*, and *identity as a future engineer*. Abbreviations of these resources are illustrated in Table 3. In addition, to understand who had determined engineering as a career choice after the camp, I was able to track 18 out of 27 participating students (Table 4).

Table 3
Abbreviations of resources and their definition

Abbreviation	Definition
M	Media (TV, Books, internet, news, seminars)
IEE	Informal engineering experience (clubs, technical service, summer camp, games)
CREP	Close relationship with engineering professional
IUEE	Informal unstructured engineering experience (playing with jigsaw puzzles or electronics tools, designing circuits)
IFE	Identity as a future engineer

I observed that *M*, *IEE*, *IUEE*, and *IFE* were resources for interest in engineering. As illustrated in Table 4, nine students (students 5, 10, 11, 13, 16, 21, 26, 1, and 14) had had no experience with engineering designs or engineering work before the camp. Yet, their attention to engineering was drawn by a flyer that had been distributed at their school. Students 4, 8, and 27 had had *IEE* with similar robotics activities before the camp. Students 4 and 8 were engineering club members at their school. They had been engaged in a one-year project in which they had designed a car. Student 4 stated, "I am a member of the engineering club at my school. I am the only girl in the club. I worked on different circuits with boys to get our car working." Student 8 added, "We designed a 4x4 car. You can use it in the desert. We made the car with brakes, gears, and an electric motor. We were lucky that our car project was funded by the school administration. However, we were faced with problems associated with the brakes. We could have tested it on a real road." Student 27 added, "We participated in a competition at a state university. We designed a robot there who could trace a line, but we used a different algorithm than what we used here. At the same time there was similarity in working principles. Both received data from sensors and worked through a microprocessor, transferring power to the motors. We only had differences in the programming and equipment used in this summer camp. Other than that, the competitions I participated in were similar to each other."

Additionally, I observed that five out of the 18 students have had *IUEE* before the camp. Student 18 expressed, "Since my childhood I have been very interested in electronic things. Like every boy, I played around with electronic tools. When I was in the second grade, I played around with computers." Likewise, Student 9 added, "Since my childhood I have been very interested in electronic tools and equipment. I was very curious about how these things work. Therefore, I used to play around with electronics and break them. I also had a tool-box that included broken things and new electronic equipment bought from the Internet. I used them to design electrical circuits." Similarly, Student 12 mentioned, "I think I have a hands-on ability to play jigsaw puzzles with equipment and materials, rather than electrical things or electronics. I used to break my toys, but I repaired them in order to make a better one." In that regard, Student 22 expressed, "What I did at home included playing with simple electrical things and electronics. For example, I had purchased copper wire to make a coil and tried to observe how a magnetic field influences the current in the wire."

I related *M* with TV, books, internet, and the news. I observed that two out of the 18 students had had some information prior to the camp about robotics through watching documentaries on TV, reading related books and newspapers, and surfing the Internet. Two students stated in their interview:

"I was already interested in robotics. I watched robotics on TV and participated in several seminars about robots. However, I did not have any experience at all." [Student 9]

"Since my childhood I have been very interested in these things [electrical and electronic].To increase my knowledge, I read books about electrical-electronics topics and watched video clips from the Internet. They were very interesting. I have been wondering how they make [robotic] cars move. These have drawn my attention." [Student 23]

I associated *IFE* with their passion to become an engineer. Some students had been interested in engineering since childhood, having had developed positive feelings toward engineering and engineering professionals. Therefore, engineering became the area of their future profession because they had wanted to become an engineer. Some students stated in their interview:

"These things have already attracted my attention. I have always wanted to become an electrical-electronics engineer." [Student 9]

"I have already made my decision on [electrical-electronics engineering]. My career should be in electrical-electronics engineering. Since elementary school, I have wanted to attend a technical high school because I love electrical-electronics stuff." [Student 27]

"My field is mechanical [engineering]. I love production and design. In addition, I want to use electrical-electronics content with my background. In turn, it can be mechatronics engineering." [Student 12]

"I had never said I would be an engineer when I was young. [However], something has sparked my interest toward engineering in the last two years and pushed me to become an engineer." [Student 3]

These resources reveal that nine students had experienced engineering design and engineering work prior to camp. During camp, the students experienced informal engineering practice and had an opportunity to work with engineering professionals as they engaged with engineering design challenges. In other words, the 18 students who were tracked gained *IEE* and had *CREP* throughout the camp. These two sources were critical for me to understand how the camp encouraged them to choose engineering as a career. According to Table 4, seven participants chose electrical-electronics engineering for a career, whereas three participants selected mechanical engineering. Two chose computer engineering, one chose industrial engineering, two chose mechatronics engineering, one chose physics engineering, and one chose energy system engineering. However, only two students chose medical science as a career.

Table 4 also indicates that nine students (students 3, 4, 8, 9, 12, 18, 22, 23 and 27) have sustained their

Table 4
Tracked Students, Resources before and during Camp, Grade Level, and Pursuing Degree

Tracked Students	Resources Before the Camp	Grade Level	Resources at the Camp	Pursue Degree*
Student 1	-	11	IEE, CREP	MS
Student 3	IUEE, IFE	12	IEE, CREP	EEE
Student 4	IEE	12	IEE, CREP	ME
Student 5	-	11	IEE, CREP	EEE
Student 8	IEE	12	IEE, CREP	ME
Student 9	IUEE, M, IFE	11	IEE, CREP	IE
Student 10	-	12	IEE, CREP	PE
Student 11	-	12	IEE, CREP	ESE
Student 12	IUEE, IFE	12	IEE, CREP	MechE
Student 13	-	11	IEE, CREP	EEE
Student 14	-	11	IEE, CREP	MS
Student 16	-	12	IEE, CREP	ME
Student 18	IUEE	12	IEE, CREP	EEE
Student 21	-	12	IEE, CREP	CE
Student 22	IUEE	11	IEE, CREP	EEE
Student 23	M	12	IEE, CREP	MechE.
Student 26	-	12	IEE, CREP	CE
Student 27	IEE, IFE	12	IEE, CREP	EEE

*ME: Mechanical Engineering, EEE: Electrical-Electronics Engineering, CE: Computer Engineering, ESE: Energy System Engineering, IE: Industrial Engineering, PE: Physics Engineering, MechE: Mechatronics Engineering MS: Medical Science.

interest in engineering by selecting engineering as their career choice. In that regard, the resources before and during camp appeared effective and motivational for these students in determining engineering as a career choice. In addition, the findings of the study revealed that the resources at the camp were more planned and outcome-oriented compared to before camp because some students (students 5, 13 and 21) selected engineering as a career choice even though they did not have any experience in engineering.

Robotics Summer Camp as a Venue for Nurturing Interest in Engineering

In this section, I present findings associated with the resources *IEE* and *CREP*. Findings from the study indicated that the robotics activities offered at the camp substantially nurtured student interest in engineering in three ways. First, the participants felt motivated to pursue engineering as a career at the camp because they were allowed to work with peers, mentors, and faculty; they were motivated to recognize and use mechanical, electronic and electrical materials (LEDs, sensors, capacitors, breadboards, AC and DC circuits, DC motors and PIC); and they were motivated to program and make a robot. The robotics activities in this process were joyful, motivating, encouraging, and challenging. Student 10, who chose physics engineering, illustrated this experience with the following quotation:

> "[Through the camp activities] we were provided with various resources and we ran several tests and trials to get the best solutions to our problems. We received help from everyone [partner, other groups, faculty members, and graduate students]. In this environment, I do think we adapted to the culture, spending over 12 hours to design our robot models, striving to solve challenges, and getting ready for the final race. So this was awesome."

Robotics summer camp provided Student 27 (who chose electric-electronics engineering) with the opportunity to utilize MicroC pro and a different type of microprocessor to design a robot, which in turn allowed him to go beyond his previous engineering experience. Thus, engaging him in designing a robot with different tools was an opportunity to maintain his interest in engineering. He expressed:

> "At this camp, I learned to also use MicroC pro and encountered the 16M628A microprocessor. To make our robot work, we worked through to the morning last night because there was a problem with the system. We made the first prototype using microprocessors and different motors and tested it, and it worked well. It was pretty joyful for us, and we were happy."

The second way the robotics summer camp nurtured student interest was by exposing the students to hands-on, minds-on, and problem-solving activities. They were provided with various race courses as challenges for designing their own robots for the final race. In turn, such opportunities encouraged them to pursue their own ideas and take ownership of their designs and learning. For Student 11, who chose energy systems engineering, it was a great opportunity that the program allowed students to solve the problems by themselves. He indicated that their problems ranged from programming to mechanical and aerodynamic issues.

> "Our aerodynamic issue was restricting the speed of our robot, and we needed to find a solution. We designed our robot with one chassis, then a second one, and finally a third one. It still did not work. We envisioned a plan in our mind, constructed it, and fixed the center of gravity, along with the programming errors. Then our robot worked very well."

It seems that the students enjoyed the autonomy given to them during the summer camp. Student 23, who chose mechatronics engineering, indicated that such an opportunity was not typically offered at their school. The robotics activities were a means for students to develop their own strategies to make a robot, to take ownership of their learning, and to do what they envisioned throughout the camp. As Student 23 explained:

> "People learn by doing. By listening to things you keep [them] in your mind, but as long as you do not do them in practice, you cannot learn. Here, we learned that learning occurs when you are engaged in practical work. I think that people can be happy when they are actively engaged in such activities."

As a third way, the data derived from the researcher's observations revealed formal and informal opportunities in which many engineering faculty members presented and talked about their research in engineering and shared their engineering education stories with the students. The participants found these presentations informative and insightful for them in choosing engineering as a career option. Student 10 expressed, "The program allowed me to see what engineering really is. What has been performed and researched in engineering was very informative for me. This encouraged me to choose this field as my career for sure."

Another student's comment on the influence of the faculty's presentations showed a clear contribution of the program to this student's future career plan, as Student 27 noted:

> "I will choose electrical-electronics engineering as a career, and then I will pursue a master's degree in robotics. In this respect, a faculty member's presentation about medical robots was very influential on my decision about robotics. Other faculty members talked about their research in engineering and projects in Turkey and in the world, as well."

In addition to the faculty members' presentations, several visiting engineering researchers and graduate students in engineering also talked about their experiences in electrical-electronics and mechanical engineering, as well as the individuals they have worked with in Turkey and other countries like the US. The students found these presentations very informative as well. For instance, Student 11expressed that before his participation in the camp, he had already known that electrical-electronics engineering was associated with electrical circuits and plans. After one of the presentations given by an engineer researcher, he realized that this engineering field has a relationship with biology as well as medicine. He noted, "These presentations enhanced my understanding of engineering per se." Student 14, who chose medical science, commented on one of the faculty members' discussions about his research topic, in which he learned how the researcher developed a robot that would be used in surgery. The point of the discussion involved how a robot can be used effectively during heart surgery, because of the heart's unstable environment. His presentation sparked the idea of how and where robots may be programmed and used. Through such a presentation, he understood what electrical-electronics and mechanical engineering might look like. After these presentations, Student 12 decided to pursue a double major, which was mechatronics engineering:

> "I talked to a faculty member here about choosing a double major [mechanical and electrical-electronics engineering] in the future. I like mechanical engineering, but you also need electrical- and electronics-content knowledge. Mechanical engineering is my area of interest; in other words, I like producing, and I like designing, but additional electrical-electronics content knowledge should be learned. Therefore, I want both [mechanical and electrical-electronics engineering]."

Similar to Student 12, Student 8 determined to pursue a degree in mechanical engineering. He stated, "[Faculty] presentations were appealing for career choice because these presentations were very informative and beneficial. I was thinking of whether to choose electrical-electronics engineering or mechanical engineering. Through these presentations I realized how different electrical-electronics engineering was, how it overlaps with other disciplines.

In sum, the robotics summer camp provided students with the opportunity to engage in robotics activities and have personal interactions with engineering researchers about engineering itself and their future career plans. The robotics summer camp provided students with the experience of robot designs and engineering challenges; close relationships with engineering professionals was a venue for nurturing their interest in engineering because among the tracked students (except students 1 and 14), they chose engineering as a career field. They have been placed in engineering programs at different universities across Turkey.

Discussion

This study aims to highlight the importance of an informal learning setting for individuals who are about to enter a university with the desire to pursue an engineering degree. Although engineering is an appealing and popular field, the number of graduates and new admissions in engineering fields is disproportionate. I provide evidence that having engineering experience before higher education by means of a summer camp is a way to maintain and nurture interest in engineering. This in turn causes high school students to pursue engineering as a career choice. Therefore, I discuss what distinguishes a robotics summer camp from school classrooms, and how this camp is a venue for nurturing interest in engineering and determining engineering as a career choice.

The findings indicate that robotics summer camps and school classrooms have different contexts in regard to *goals*, *practical work*, and *social structure*. In this sense, goals, practical work, and social structure are not mutually exclusive; instead they are complementary. In the context of the school classroom, students are expected to succeed on the nation-wide university entrance exam. Therefore, they need to enhance their readiness for the exam as they memorize content knowledge and gain ability to solve the exam questions in a short time. Their future life after high school depends on this exam (Akkok & Watts, 2003; Caner & Okten, 2010), so they have to reach their goal through the teaching strategies provided within the social structure grounded on the teacher's authority of knowledge and individualized learning. To succeed on the exam requires their teacher to prepare relevant learning materials, follow curriculum objectives, and recognize the content of the exam. This can limit instruction to mainly lectures and memorization, with minimal interaction from others or collaboration. The reality of the exam discourages teachers and students from going beyond the content of the exam; although a few students through their will and curiosity develop and sustain interest in engineering through robotics activities by the time school finishes. In other words, school classrooms fail to provide individuals with the opportunity to transcend schooling objectives, whereas the summer camp does so in a way that engages students with more hands-on and minds-on activities in a more flexible and collaborative context where experience, knowledge, and ideas are shared, and where mutual interactions allow them to reach their goal. These differences make the robotics summer camp a venue for attracting student attention to and fostering interest in engineering, and for determining to pursue a degree in engineering, which is in agreement with the studies of Ruiz-el-Solar (2010), Weinberg et al. (2001), and Yilmaz et al. (2010).

I extend my discussion about the differences between the robotics summer camp and science classrooms in terms of the framework of Engle and Conant (2002). With respect to *problematizing content*, the students were engaged with challenges in the camp, as opposed to the school classroom. In the science classroom, students were provided with science subject-matter to be memorized rather than with challenging ideas because they were expected to confirm the given knowledge through simple laboratory applications. The problem that the team organization presented to the participating students was to design a robot that could track a line and complete a race course. However, Benke (2012) claims that both robotics competitions and school classrooms are similar in the sense that students are provided with *predefined* problems. In the case of this study, the students were given the task of designing a robot that would work properly on each race course, constituting a predefined problem. In addition, the students met with various problems (aerodynamic, programming, and mechanical) throughout the iterative process as they designed their robot models and tested, redesigned, and retested them. These problems emerged because the organization team had problematized the content by spontaneously changing the parameters or rules (decreasing the number of sensors, increasing the difficulty level of each race, increasing the number of tricks on the race courses, and imposing penalty conditions). The core idea behind this was to show the students the nature of engineering and allow them to experience how engineers respond to emerging problems. Then, the students generated their best solutions for these problems by themselves, or with their mentors' help, if necessary. As a result, this case is aligned with Puvirajah, Verma, and Webb's (2012) study in terms of problematizing content as provided in informal learning settings. Moreover, problematizing content seems to allow individuals to become competent as they are dealing with challenges and problems unexpectedly (Deci et al., 1991; Hagay & Baram-Tsabari, 2015).

As for *giving students authority*, the students were given the authority to accomplish their task. In other words, they were responsible for completing their tasks and they were active in performing their activities. The organization team leader organized the paired groups. In turn, this allowed the students to mingle and collaborate with others. This arrangement encouraged them to design their models, generate solutions to the problems, and take ownership of their own products, all of which supported active student engagement. However, Benke (2012) claims that there is a hidden authority established in robotics competitions because some group leaders may dominate team members, just as a teacher does in the classroom, on the basis of their authority of knowledge. In the case of this study, I observed that the twelve-paired groups worked in tandem and shared their findings, designs, and solutions for specific problems both within the group and with the other groups. I did not witness the teacher's institutionalized role in the paired groups, and thus a hidden authority did not exist in the paired groups for several reasons. First, the groups were limited to two students, with no team leader at all. Instead, two students were co-leaders. Second, most of the participating students did not have any experience with robotics activities. However, those who had experience with robotics did not dominate their group members, rather, they helped each other. Third, the two students in each group sought to resolve their problems and answer their questions through mutual interaction; if they did not find solutions or answer by themselves, they requested help from other groups and their mentors. Thus, in line with the study of Puvirajah et al. (2012), giving students the same level of authority, without dominance by one based on greater experience or knowledge, enhanced student engagement in the robotics activities. In turn, such engagement allowed individuals to initiate and regulate their actions; namely, they became autonomous (Deci et al., 1991; Hagay & Baram-Tsabari, 2015).

In terms of *holding students accountable to others and to disciplinary norms*, the individuals in the paired groups were held accountable to each other in designing a working robot that could compete in the final race. At the same time, they were held accountable to disciplinary norms, which in my case included working together in harmony, sharing their experience and knowledge with one another, and seeking solutions for problems without dominating each other. None of these features characterized the settings in their school classrooms, because in school they were dominated by the teacher in performing schooling tasks (Puvirajah et al., 2012); furthermore, they were also encouraged to learn more individually to prepare for the national exam. Yet at the camp, accountability to others and to disciplinary norms as they engaged with activities promoted a warm atmosphere between the camp participants and the organization team. Although the camp was competition-oriented, friendships happened among the student groups. This can be associated with "relatedness" as mentioned in Deci et al. (1991) and Hagay and Baram-Tsabari (2015).

As for *providing relevant resources*, the students were provided with the necessary materials and information to design a robot to compete in the final race. I observed that most of the students from various high schools had access to materials and information for performing hands-on and minds-on activities. In the school activities, however, they were restricted to performing the objectives in a traditional way due to time constraints and exam requirements.

What distinguished the camp from the classroom with respect to fostering students' interest in engineering was not the competition per se. Instead, the camp offered an informal learning experience with contextualized activities that allowed the students to perform engineering activities and develop a close relationship with engineering professionals. The context of the camp included robotics activities representing the four principles of *problematizing content, giving students authority, holding students accountable to others and to disciplinary norms,* and *providing relevant resources.* In turn, this context enabled the students to productively engage in activities (Verma et al., 2015) which fostered their interest in pursuing a career in engineering. Thus, the study findings can be used to design a learning context where students are motivated to perform similar tasks for fostering and sustaining their interest in engineering.

In terms of determining to pursue a degree in an engineering field, as mentioned above, 18 out of the 27 students had been tracked to explore whether or not they chose engineering as a career choice. Only two students selected medical science as a career choice. Before the camp, both had expressed that they did not have any experience with engineering. Yet, both were exposed to engineering practices and had an opportunity to develop a close relationship with engineering professionals. Even though both came to the camp with an intention to learn and experience engineering, they were placed in medical science due to the university entrance exam, which considerably eliminates and ranks students according to their scores. While the university entrance exam pushes students to make a choice based upon their score, students list their choices as they desire.

Furthermore, interest is associated with the interaction between a person and a particular content (Hidi & Renninger, 2006). Once this interaction is sustained through contextualized activities, interest will not abate over time (Barab & Plucker, 2002; Dabney et al., 2012). As added by Bathgate et al. (2014), if context, manner of interactions, and topics are utilized effectively, then interest may be sustained. In the case of this study, the high school students interacted with robotics activities that were generally not offered at their schools. These activities fostered their interest in engineering because they were joyful, motivating, and encouraging, which in turn allowed the students to develop their own strategies for making a robot, taking control of their learning, and doing what they envisioned during the camp. In addition, the students were in very close contact with the organization team members, and the faculty presentations and personal talks with visiting engineering researchers, graduates, and senior undergraduate students were a means for them to understand the nature of engineering, to become familiar with the interdisciplinary aspects of engineering, and to decide to choose engineering as a career. Additionally students' psychological needs associated with autonomy, competence, and relatedness were bolstered throughout the camp activities.

Conclusion and Future Research

This study highlights the characteristics of a robotics summer camp, elicits the differences between camp and school activities, and reveals the resources that support student interest in engineering through robotics activities. The findings offer some solutions to three problems—*lack of engineering practice in K-12 Turkish curricula*, *the nature of school counseling and consultation services*, and the *perception of engineering in society*, which are all associated with the disproportionality of the number of new admissions in engineering sciences to the graduates. The robotics summer camp deals with these problems in several ways. First, the camp offers informal learning experiences through robotics activities that are distinct from formal school activities, allowing the students to be able to gain first-hand experience with engineering design, challenges, and content. Second, the robotics activities engage the students in an iterative process that allows them to experience engineering work before higher education. Third, the robotics activities trigger and sustain student interest in engineering and encourage them to choose engineering as a career. Fourth, the camp allows students to consciously determine engineering as a career choice due to active engagement in engineering practices, providing support for autonomy, competence, and relatedness, namely, intrinsic motivation. Thus, the robotics summer camp as a social context supports individuals in developing and sustaining interest in engineering as they are engaged with engineering activities which mesh with their passions and self-interests.

It seems that informal learning settings like the robotics summer camp are a venue for students to gain first-hand experience, to develop and sustain interest in engineering, and to comprehend the multidisciplinary nature of engineering in general. This in turn helps students to determine their career choice and sustain lifelong interest in engineering. Therefore, these characteristics differentiate summer camps from school consultation and counseling services in regard to the active participation in engineering work as opposed to exposing them to lecture-based, university visits.

Further research can be carried out to investigate whether the tracked students have still maintained their interest in engineering, and explore possible factors which trigger them to continue their career in engineering. In that regard, engineering-related values can be elicited to indicate if they had made an appropriate choice in pursuing a degree in the fields of engineering. In addition, learning scientists or engineering researchers can conduct a longitudinal study to uncover any transition from situational interest to personal interest in engineering within the context of interest development and self-determination theory in different learning settings. Also, a part of future research can focus on the ones who had selected medical science rather than an engineering program because these two students had not had any experience with engineering before the camp but they had had engineering experience and a close relationship with engineering professionals. After such experiences and engagements they were placed in medical science. Is it completely related to the university entrance exam system or is it related to their interests and desires in pursuing a degree in medical science?

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