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The Impact of Engineering Design-based Activities on Eighth-Grade Students' Environmental Awareness and Entrepreneurial Perceptions and Skills

Mehmet Ali Küpeli[1], Sedef Canbazoğlu Bilici[2], S. Selcen Guzey[3]

ABSTRACT

Research Article

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This study examined the impact of engineering design-based, thematic activities on 8th-grade students' environmental awareness and entrepreneurial perceptions and skills. The engineering activities were designed to introduce topics and issues that are tied to energy conversion and environmental science. Thirty-seven students (21 girls, 16 boys) completed the activities and participated in the one-group pretest-posttest quasi-experimental study. The data were gathered using the Environmental Awareness Scale (EAS), Entrepreneurial Perception Scale (EPS), and student worksheets and artifacts. Entrepreneurial skills were assessed using the Entrepreneurial Skills Checklist (ESC). Descriptive statistics and paired-samples T-test were conducted for data analyses. Results showed a significant difference between students' pre-test and post-test scores of the EAS and EPS which indicated that the engineering design-based activities greatly impacted the eighth-grade students' environmental awareness and entrepreneurship perceptions. These activities also contributed to the development of students' entrepreneurship skills such creativity, critical thinking, self-confidence, social skills and group work, leadership, decision-making, and risk-taking. This study offers insight into engineering design-based activities and promotes the development of students' environmental awareness and entrepreneurial perceptions and skills in the middle school science classroom.

Keywords: Science education; Engineering design process; Entrepreneurship; Environmental awareness

[1] Science Teacher, Republic of Turkey Ministry of National Education, Turkey kupelimehmetali@gmail.com, 0000-0003-4953-2617

[2] Assoc. Prof. Dr., Gazi University, Turkey, Department of Science Education, sedefcanbazoglu@gazi.edu.tr, 0000-0001-7395- 6984

[3] Assoc. Prof.Dr., Purdue University, USA, Department of Curriculum and Instruction and Department of Biological Sciences, sguzey@purdue.edu, 0000-0002-7982-3960

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INTRODUCTION

Today, the need for individuals who approach problems from different perspectives, produce innovative solutions, and have 21st-century skills is steadily increasing. The 21st-century skills such as entrepreneurship, the ability to use creative problem solving approaches, take risks, and evaluate and communicate information is critical for success in the global economy (Drucker, 2014). The term "entrepreneur" was first introduced in the early 18th centuries in French economics. An entrepreneurial individual has been defined as a person who promotes economic growth by innovating and creating new products and services (Akçin, 2021). European Commission Working Group on Entrepreneurship Education defines entrepreneurship as "a key competence for all learners, supporting personal development, active citizenship, social inclusion and employability" (European Commission, 2015a, p.8). According to The Turkish Qualifications Framework (TQF), a "sense of initiative and entrepreneurship" refers to an individual's ability to turn ideas into action. Entrepreneurship is often associated with creativity, innovation and risk-taking, and the ability to plan and manage projects to achieve objectives (Vocational Qualifications Authority [VQA], 2015, p.24). In addition, entrepreneurship is characterized as developing commercial products and gathering production-related factors to solve problems and needs (Ürper, 2015) and is mainly associated with the economy and industry. In this era, it is essential to help students build entrepreneurship skills and develop entrepreneurial mindset. To do that, efforts should be made to provide entrepreneurship-focused education that encourages entrepreneurship, creativity, innovation, problem solving, and collaboration (Yurtseven & Ergün, 2018).

With the emphasis placed on entrepreneurship education in the K-12 education system in Turkey, students are now provided opportunities to develop entrepreneurship skills starting from kindergarten. These critical skills include seeing problems as opportunities, gathering resources and key information to develop solutions to problems, developing and implementing projects, innovating, and managing and organizing strategies. Commercial entrepreneurship becomes the main focus of entrepreneurship learning experiences at the secondary school level. Entrepreneurship education is integrated in the national science curricula which provides guidelines and instructional materials for the teachers (Ministry of National Education [MoNE], 2009). For example, one of the main objectives of the middle school science curriculum is to develop students' career awareness and entrepreneurship skills related to science. The curriculum includes core science concepts and practices of science, engineering, and entrepreneurship. Within the program's scope, students are primarily expected to define daily needs or problems related to the identified core science concepts. The national curriculum suggests that solving problems improve tools, objects, or systems being used. In addition, the process involves material, time and cost management. Students brainstorm solutions, compare alternative solutions, and choose the appropriate one within the scope of criteria and constraints. They are also expected to communicate design solutions. This whole design and production process is carried out in the school environment. It is important to note that, students are required to conduct experiments during the product development phase, analyze data, and use scientific data in the design process. This integrated approach aims to improve students' entrepreneurship skills with engineering design-based science activities in the curriculum. To help building entrepreneurial skills, students are expected to create strategies and use promotional tools for marketing the product they have designed in an engineering design-based task. For example, "students are recommended to make public service announcements or short films to promote their products" (MoNE, 2018, p.10).

As discussed in the Turkish national science curriculum, integrated STEM (Science, Technology, Engineering, and Mathematics) activities provide a rich learning environment to develop students' entrepreneurship skills (Ezeudu et al., 2013; Uçar, 2020). Previous research also demonstrates that interdisciplinary learning environments should be created to enable students from a young age to gain entrepreneurial experiences in and out of school (Karakılçık & Uçar, 2022; Nambisan, 2014; Rina et al., 2019). Integrated STEM education is an essential interdisciplinary approach for students to acquire entrepreneurship skills such as creativity, innovation, critical thinking, and risk-taking. The STEM education reform movements worldwide emphasize the importance of interdisciplinary learning experiences and the development of interdisciplinary knowledge and skills in K-12 (Herdem & Ünal, 2018; Sahin et al., 2014). One of the primary purposes of STEM education is to educate creative, innovative, competitive entrepreneurs and problem-solvers who can apply knowledge and skills from different disciplines to problems (Sanders, 2009). There are many approaches to STEM education. Bryan and Guzey (2020) noted that "the ubiquitous use of the term STEM, with little definitional consistency, runs the risk of diluting its potential value for enhancing, reforming, and informing K-12 research, policies, programs, and practices" (p. 6). The authors use the term to refer to an instructional approach that uses engineering design as a vehicle for teaching and learning science. Engineering is a natural connector to integrating STEM disciplines since design solutions require applying knowledge and skills from science and mathematics. The engineering design process is "(1) highly iterative; (2) open to the idea that a problem may have many possible solutions; (3) a meaningful context for learning scientific, mathematical, and technological concepts; and (4) a stimulus to systems thinking, modeling, and analysis (National Academy of Engineering & NRC, 2009). Recent K-12 education reforms emphasize the necessity for students to understand engineering and practices. For example, the European Commission report on science education authors states that K-12 education should emphasize engineering design and highlight emerging technologies in engineering education to help students pursue careers in STEM (European Commission, 2015b). It is essential for K-12 students to engage in various STEM education activities focusing on engineering concepts and practices for development of entrepreneurial skills (European Commission, 2018).

The STEM activities should be realistic, authentic, and relevant to students' lives. The interdisciplinary nature of environmental problems (air and water pollution, climate change, etc.) we encounter daily require utilizing STEM knowledge and entrepreneurship skills to solve them (Nambisan, 2014). Environmental education helps students make informed decisions and engage in problem-solving processes to solve ecological issues (Erten et al., 2003). The general purpose of environmental education is to raise environmentally conscious and sensitive individuals to teach students about the effective and efficient use of natural resources, determination of ecological limits, prevention of depletion and pollution, and promote environmental awareness (Güven, 2011). Being environmentally aware means understanding the consequences of our behavior and choices to the environment, making environmentally-conscious decisions, and committing to making changes to protect the environment. Many environmental problems are constantly occurring in today's world, and there is a critical need for increasing environmental awareness. This can be achieved by providing students opportunities to engage in engineering design activities that require them to develop solutions to environmental problems. To this end, we developed a series of engineering design-based, thematic science activities that focus on energy conversion and environmental science. These activities were used to give secondary school students the responsibility develop solutions for design challenges and, in turn, develop their entrepreneurship skills (Deveci & Çepni, 2014; Middleton et al., 2014). The current study aimed to address the following research question:

- What is the impact of the engineering design-based activities on students' environmental awareness, entrepreneurial perception, and entrepreneurial skills ?

METHOD

The one-group pretest-posttest quasi-experimental design was used in this study. The one-group experimental design allows researchers to establish causal relations between problems identified in the research (Shaughnessy et al., 2006).

Participants

The convenience sampling method was used to determine the study participants. The research sample comprised of thirty-seven 8th-grade students (21 girls, 16 boys) from a public school in Turkey.

Data Collection Tools

The data were gathered using the Environmental Awareness Scale (EAS), Entrepreneurial Perception Scale (EPS), and students' worksheets and artifacts.

Environmental Awareness Scale (EAS)

EAS was used to assess the impact of engineering-based activities on the environmental awareness of the eighth-grade students before and after they engaged in the activities. It was developed by Güven (2011), considering the cognitive steps of Bloom's Taxonomy, and consisted of 44 items on a Likert-type scale (3=Yes; 2=No idea; 1=No). The scale includes sub-factors in the cognitive domain: knowledge, comprehension, application, analysis, synthesis, and evaluation. The EAS's reliability was established through Cronbach's Alpha, which was found to be .79. Therefore, the scale is considered to have high internal consistency.

Entrepreneurial Perception Scale (EPS)

EPS was utilized to assess the engineering activities' impact on the students' entrepreneurship perception levels before and after the activities. It was developed by Özcan (2019) and consisted of 28 items. There are five sub-dimensions in the scale: perception of innovation and creativity, self-confidence, leadership and taking initiatives, social skills and group work, and risk-taking tendency. The scale has a high Cronbach's Alpha, calculated as .85.

Entrepreneurship Skills Checklist (ESC)

ESC was used to measure the impact of the activities on the students' entrepreneurship levels. It is a checklist developed by Çetin (2015) and includes 26 items with six sub-dimensions: creativity, innovation, risk-taking, critical thinking, need to succeed, and interpersonal relations. The checklist was scaled as "weak, average, good, very good." The highest score on the checklist is 104, and the lowest score is 26.

Students' artifacts

Artifacts were collected through worksheets and engineering design-based product presentations. Worksheets were developed according to the engineering design cycle (Hynes et al., 2011). Three experts in STEM and engineering education reviewed the worksheets. Necessary changes were made to the worksheets based on the feedback provided by the experts in the field. During the activities, the students answered the questions on the worksheets as a group. However, they brainstormed ideas and solutions to the design problems individually first and then as a group. Groups presented their products to their peers. Presentations focused on production planning, marketing, sales, and after-sales services. Design presentations and worksheets were collected and analyzed.

Procedures

Students engaged in three engineering design-based activities focused on energy conservation and environmental science themes. Activities were carried out during an elective course named Environmental Education (six hours a week). Table 1 summarizes the five-week-long study timeline.

Table 1. Overview of the Research

Week	Content
1	Implementation of the pre-test (EAS & EPS) Introduction to engineering: What is engineering? What are the steps of the engineering design process?
2	Sun-loving school design activity
3	Botanic garden science field trip Eco-friendly vehicle design activity
4	Water filter design activity
5	Implementation of the post-test (EAS & EPS)

Each design activity was completed in six 40-minute class periods, and students used the engineering design process (Hynes et al., 2011) to solve the given design challenges. In the "Sun-loving school activity," students were asked to design a sustainable, green school that saves energy and environmental resources. The design criteria fell into several groups in this activity, including energy conversion, cost, time, and aesthetics. In this activity, students collected and analyzed temperature changes that can be used to evaluate the effectiveness of their designs.

Figure 1. Students make their design as a team

In the “Eco-friendly vehicle design” activity, students evaluated the air quality measurement of the city that they lived in. They then discussed the following questions to help them recognize the problem: “In your city, between 2017 and 2022, what is the air-pollution parameter that increased the highest?”, “How do air-pollution parameters change in the daytime and at night?”, “What might be the factors affecting this change?”, “What factors do you think cause air pollution?”, “What can be done to reduce the air pollution resulting from transportation?” Next, the students were asked to design a vehicle by analyzing the structures and movements of living creatures in the nature. The number of DC engines used in the designed vehicle, the distance covered by the vehicle in the determined time, the energy conversion in the vehicle, the vehicle's cost, its aesthetics, and time to complete the design task were set as the design criteria for the activity. Students visited a local botanical garden to observe and collect data to identify a living organism to mimic their eco-friendly vehicle’s features.

In the “Water filter design activity,” a graph showed the per capita wastewater generation rates in the City was shared with the students to identify the year with the highest proportional increase in the amount of wastewater and discuss the reasons for the rise, and possible solutions to reduce wastewater formation. Then, the importance of water for living creatures, factors that cause water pollution, and the depletion of water resources were discussed. Students were then asked to design a portable water filter for wastewater reuse. Following the engineering design process, the students built their designs using zeolite, activated carbon, natural sand, pebbles, tree leaves, coal, fabric, bottles, and cotton. At the end of the activity, the Total Dissolved Solids (TDS), pH and conductivity values were measured three times before and after the water was filtered and averaged. The amount of water purified per minute from the designed filter was compared with the initial average values by taking note of the TDS, pH, and conductivity values of the treated water.

In all three engineering activities, entrepreneurship-related dimensions have been added to the engineering design steps (Deveci, 2018), especially highlighting the social and cultural dimensions of entrepreneurship, apart from its financial dimension. Until problem identification and product testing, attention was drawn to the cost, estimated sales amount, innovative aspects of the product, and the possible risks. During the design product presentation, each group was asked to produce a catchy slogan. The groups were acting as entrepreneurs and they were asked to present their designs to their classmates, explaining "production planning, marketing, sales, and after-sales services." Thus, students research how environmental and economic issues are affected by science and technology and manage the time, cost, and accessibility constraints.

Data analysis

The descriptive statistics and paired-samples T-test were used for data analysis since the data obtained from the EAS and the EPS were found to have a normal distribution. The eta-squared (η^2) coefficient was calculated to determine the effect size. The first author and an independent observer weekly analyzed students worksheets, design products, and the presentation of the products utilizing the ESC. Each used the entrepreneurship skills checklist independently. Next, the averages of scores for each activity were calculated, and each sub-dimensions change on the checklist was examined. Cohen's Kappa was adopted to determine the reliability of the agreement between scores given to checklists by the first author and the observer, which was calculated to be .82.

RESULTS

Environmental awareness

A paired-samples t-test was conducted to evaluate the impact of the engineering design-based thematic activities on students' scores on the EAS. As shown in Table 2, there was a statistically significant difference between pre-test [M=100.324, SD=7.337] and post-test results [M=124.729, SD=3.404, t (36) =27.424, p<.0005]. The eta squared ($\eta 2 = .95$) indicated a high effect size.

Table 2. A Paired-samples T-test Results on EAS' Pre-test and Post-test Scores

	N	*M*	*SD*	*t*	*df*	*p*	η^2
Pre-test	37	100.324	7.337	27.424	36	.000	.95
Post-test	37	124.729	3.404				

Entrepreneurship perception levels

A paired-samples t-test was conducted to evaluate the impact of the engineering design-based thematic activities on students' scores on the EPS. As shown in Table 3, there was a statistically significant difference between pre-test [M=93.567, SD=14.814] and post-test results [M=114.675, SD=10.181, t (36) =6.626, *p*<.0005]. The eta squared ($\eta 2$: .73) indicated a high effect size.

Table 3. A Paired-samples T-test Results on EPS' Pre-test and Post-test Scores

	N	*M*	*SD*	*t*	*df*	*p*	η^2
Pre-test	37	93.567	14.814	6.626	36	.000	.73
Post-test	37	114.675	10.181				

Entrepreneurial skills

ESC was used to evaluate the changes in students' entrepreneurship skills during engineering design-based activities. As shown in Figure 2, the groups' average scores increased from the first to the last design activity. The lowest average score in the Sun-loving school activity was observed in innovation and interpersonal relations. In the first activity, the students received the highest score in the creativity dimension. For the eco-friendly vehicle activity, the highest score increase was observed in the risk-taking dimension. As for the water filter activity, students' risk-taking and critical thinking skills greatly improved. The lowest improvement occurred in the creativity sub-dimension.

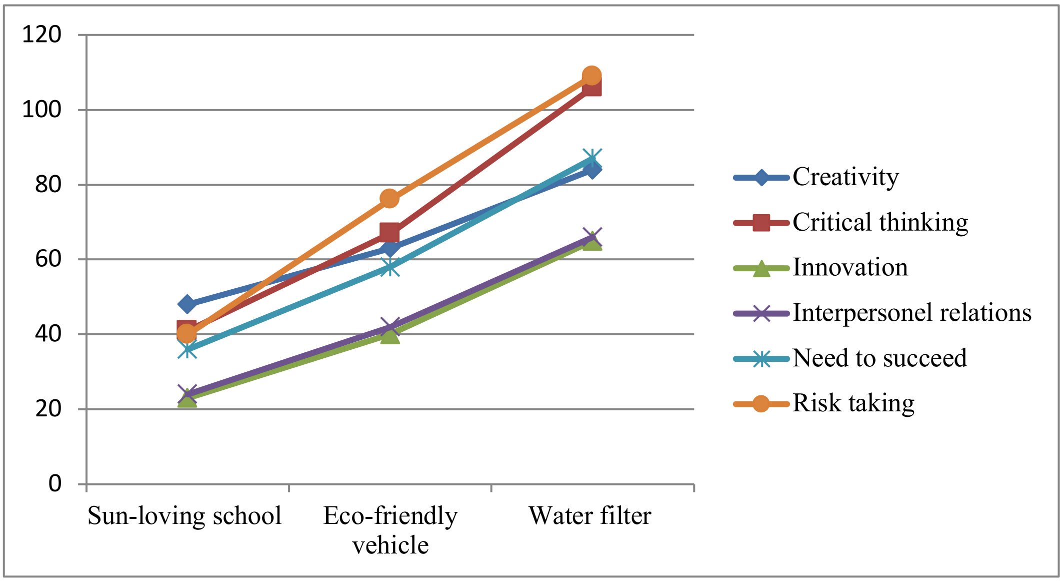

Figure 2. Average of students' entrepreneurship skills score

DISCUSSION AND CONCLUSION

This study examined the impact of engineering design-based activities on 8th-grade students' environmental awareness, entrepreneurial perceptions, and skills. The activities were designed around a specific theme, energy conversion, and environmental science. Results showed a significant difference between the pretest-posttest average scores for environmental awareness. Engineering design-based activities that focus on environmental science activities positively impacted the students' environmental awareness. The results of this study support previous findings that points out the benefits of design-based activities on students' environmental awareness. Gottfried (2015) found that STEM education activities increased students' environmental awareness, attitudes, and motivations. Çalışıcı (2018) also reported that STEM activities performed with eighth-grade students within the Living Creatures and Energy Relations unit positively affected students' environmental awareness and attitudes.

The current study also showed that engineering design-based activities positively impacted the students' entrepreneurial perceptions. This finding also supports prior studies reporting that engineering design-based activities positively impacted the students' entrepreneurial perceptions (Shahin et al., 2020). Similarly, Turgutalp (2021) found that activities based on the STEM 5E model improved middle school students' entrepreneurial skills and increased their academic success. The explored increase in entrepreneurial perceptions is regarded as an improvement caused by the students' participation in the entrepreneurship-focused STEM activities.

Concerning the entrepreneurial skills, the highest increase was observed in risk-taking skills. The risk-taking skills were greatly improved after the eco-friendly vehicle activity, which was carried out in the botanical garden. Çepni and Deveci (2014) state that out-of-school learning environments encourage students to take risks and help them develop risk-taking skills. Similarly, Uçar (2020) proposed that engaging in risk-taking problems related to environmental issues is important for students to reveal and develop risk-taking skills. In this study, students' focus on environmental issues they encounter in their daily lives may have contributed to the development of risk-taking skills.

The findings also showed an increase in the descriptive values of the creativity sub-dimension after the activities. According to Aktamış ve Ergin (2006), in science education, creativity is the ability to produce solutions when facing a problem or situation. Konca-Şentürk (2017) found that engineering design activities positively contribute to the development of students' creative thinking skills. In conclusion, this study found that environmental science-based thematic engineering design-based science activities increased students' environmental awareness and entrepreneurship perceptions and skills.

Limitations and Recommendations for Future Research

This study offers insight into understanding the engineering design-based activities and their influence on the development of students' environmental awareness and entrepreneurial perceptions and skills in the middle school science classroom. The study has several limitations. First, due to the number of study participants, the researchers didn't perform any comparison or analysis based on the gender of the participants. Therefore, further studies may be conducted with groups displaying a near-equal distribution of gender. In addition, since students worked in small design groups, the entrepreneurial skills checklist was used for groups. Also, in this study, the examined sub-dimensions for entrepreneurship were creativity, critical thinking, innovation, interpersonal, need to succeed, and risk-taking. In another study, other sub-dimensions of entrepreneurship skills could be addressed. Finally, a future study could use a different learning environment such as an out-of-school learning setting, include students from different grade levels, or focus on different science concepts to further document the benefits of engineering design activities on students' environmental awareness and entrepreneurial perceptions and skills.

Ethical Rules: In this research, the ethics committee approval notification document containing the eligibility decision for the research was received from the Aksaray University Human Research Ethic Committee (Date: 19.09.2019, No: 2019/08-12). All ethical procedures were followed during and after completing the study.

Authors Contributions: This study was written on the basis of the first author's master's thesis titled "The effect of engineering design activities on the environmental awareness, entrepreneurship perception and skills of 8th grade students" which was completed on January 21, 2021. The subject of the study was suggested by the second and third authors. The first author developed engineering design-based activities. The second and third authors examined the activities. Evaluation of the findings, discussion, conclusion, and development of suggestions were performed by the first author and supervised by the second author. Third author also contributed to literature review and discussion parts of this study.

Conflict of Interest: No potential conflict of interest was reported by the authors.

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