

The Effect of Engineering Design-based STEM Activities on Students' Entrepreneurial Skills

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ABSTRACT This study aims to reveal the effect of engineering design-based STEM activities on the entrepreneurial skills of seventh-grade students. In this context, students were asked to design engineering design-based STEM activities for problems identified using real-life situations. At the end of this process, an attempt was made to determine whether their entrepreneurial skills had changed in response to the solutions they developed to the problem. The research used a mixed-methods sequential design, first collecting quantitative data and then qualitative data to examine in depth the reasons behind the quantitative results. The participants in the research were 50 seventh-grade students, 26 in the experimental group and 24 in the control group, attending a state secondary school. The data collection tools used in the study were the Science-Based Entrepreneurship Scale and a semi-structured interview guide. The study found that engineering design-based STEM activities positively affected the development and improvement of students' entrepreneurial skills. The participants stated that they enjoyed the application process, remained active throughout, and that a student-centred approach was effective in achieving these results. The participants emphasised that it was a process that developed their entrepreneurial skills and changed their perceptions of entrepreneurship.

Keywords: Entrepreneurship, STEM education, Engineering design cycle, Science education

1. INTRODUCTION

In the 21st century, rapid renewal, change, and development are occurring across many fields, such as the economy, technology, and industry. Countries worldwide are in a race across all these fields. In this process, it is important to provide individuals with knowledge and skills appropriate to their age in education and training processes. However, countries can come to the forefront in this race by attracting individuals with this knowledge and these skills. These skills that individuals should have are expressed as 21st-century skills. These skills include critical and creative thinking, problem-solving, entrepreneurship, communication, cooperation, leadership, responsibility, curiosity and imagination, creativity, and innovation (Partnership for 21st Century Skills [P21], 2009). Rapidly increasing populations and the need for employment, technological advances, financial competition, and scientific developments have globally changed the profile of the qualified people societies need to raise. In the 20th century, the development of science and technology was shaped by countries' efforts to access, develop, and use information (Ursavaş & Karal, 2019).

However, today there is a greater focus on the skills individuals should have to prevent global problems caused by the uncontrolled use of information (Prajapati, Sharma, B., & Sharma, D., 2017).

"21st century skills" are essential for individuals to cope with the challenges of the age, solve complex problems, and play an active role in economic development (Rae, Martin, Antcliff, & Hannon, 2010). STEM (Science, Technology, Engineering, Mathematics) education is gaining attention as an effective way to develop these skills. STEM education is a teaching system that aims to integrate the disciplines of science, technology, engineering, and mathematics, with a basic approach of application (Bybee, 2010). The fact that developed countries focus on subjects related to science, technology, engineering, and mathematics parallels their developed economies (Mercan Höbek, 2014). In the 21st century, students need to draw on more than one discipline to solve the complex problems they face (Moore et al., 2014). Therefore, it is

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recommended that disciplines be taught in an integrated manner rather than separately (Turiman, Omar, Daud, & Osman, 2012). In Turkey, various studies have been conducted to keep up with these developments. National Science and Technology Policies 2003-2023 Strategy Document prepared by TUBITAK (2004), STEM Education Turkey Report published by Akgündüz et al. (2015-a), Vision 2050 Turkey Report presented by TUSIAD (2011), and 2023 Vision Document of the Ministry of National Education (2018) draw attention in this regard. In these documents, it is emphasised that science, engineering, technology, and mathematics disciplines should be taught by integrating them, and that raising students as individuals with knowledge and skills in these fields is a primary goal.

In recent years, the concept of entrepreneurship has started to attract attention in the field of education, leaving the fields of economy and business. The European Commission has stated that entrepreneurship should not be limited to the economic field (European Commission, 2013). Because of the rapidly changing world, scientific studies and technological innovations are creating new professions, and changes are also occurring in existing employment areas. In this respect, the concept of entrepreneurship has gained importance in acquiring knowledge and skills to ensure that individuals are employed in new professions (Deveci, 2016a). Entrepreneurship is a way of thinking and acting that affects society and the economy, and it involves business skills that initiate new initiatives (Developing Entrepreneurial Graduates, 2008). According to İşcan and Kaygın (2011), entrepreneurship emerges with the combination of economic, cultural, social, psychological, technological, and personality characteristics. According to another definition, entrepreneurship is about realising and using opportunities rather than just having resources (Stevenson & Jarillo, 2007). Entrepreneurship means creating a new organisation or transforming an existing one into a different business, service, or work by taking risks (Ağca & Yumuşakipek, 2015). Achor and Wilfred-Bonse (2013) say that entrepreneurship is the ability to focus on new business ventures, gather information, and plan to start a new business. In entrepreneurship, people generate new ideas, spread and implement them faster, and help new industries grow. This makes technology-using sectors more productive and creates fast-growing sectors, making entrepreneurship more important (Özcan, 2019). According to another definition, entrepreneurship is defined as the ability to employ oneself; find, create, and fill market gaps; anticipate faith-based, psychological, and social risks; and create new things while anticipating risks and rewards (Hisrich & Peters, 1989). According to Fayolle & Gailly (2008), entrepreneurship is a concept with several sub-dimensions, including risk-taking, innovation, decision-making, and creativity. Entrepreneurial

individuals discover, select, evaluate, and utilise opportunities (Ferrante, 2005; Shane & Venkataraman, 2000). If it is necessary to make a definition of entrepreneurship based on the existing definitions of entrepreneurship in the literature, entrepreneurship is the ability of individuals to develop a product and to promote and market this product most effectively by using their skills of creativity, innovation, risk taking, evaluating opportunities, forecasting, effective communication, being courageous and decisive, making plans, financial management, and using resources effectively by recognising themselves.

Education plays a vital role in developing the attitudes and behaviours that entrepreneurial individuals should possess (European Commission, 2004; European Commission, 2008). Thanks to entrepreneurship education, it is seen that participants' skills in finding business ideas improve (Morrison, 2000), self-efficacy increases (Wilson, Kickul, & Marlino, 2007), entrepreneurial goal setting ability improves (Soutaris, Zerbinati, & Al-Lahan, 2007), entrepreneurial career focus (Wilson, 2008-a), entrepreneurial attitudes increase (Florin, Karri & Rossiter, 2007). The earlier students are exposed to entrepreneurship education, the greater the increase in their entrepreneurial characteristics, so entrepreneurship education should be provided long before they enter higher education (Wilson, 2008b; Fakharzadeh, 2012). When the content of entrepreneurship education is examined, it aims to develop skills such as risk-taking, planning, analysis, organising, teamwork, communication, and the ability to see opportunities, as well as a command of economic functioning (Deveci, 2016b). In our country, the fact that the theoretical part of entrepreneurship education, which is mainly taught in secondary education and universities, is inadequate in its application is a serious problem (Kurnaz, 2017). In this context, entrepreneurship education should not be confined to textbooks; it should be grounded in real life, where individuals can take risks, manage the results, discover opportunities, and offer them to others (Çelik, 2018). From this point of view, entrepreneurship education requires an interactive teaching process in which innovative learning skills are utilised and multiple disciplines are used together (World Economic Forum, 2009). In Turkey, there was no direct emphasis on entrepreneurship education in science curricula until 2013 (European Commission, 2013). However, in the 2013 curriculum update, analytical thinking, teamwork, creativity, communication, decision-making, and entrepreneurship skills were highlighted within the scope of life skills (MoNE, 2013). In the programme renewed in 2018, engineering and design skills were added to science and entrepreneurship skills (MoNE, 2018). The programmes aim to support economic empowerment by focusing on developing students' innovation, creativity, and entrepreneurship skills (Deveci, 2016-c). In 2024, within the framework of the "Turkey

Century Education Model", entrepreneurship skills have an important place in science education. Within the scope of this model, 13 field skills were added to the science course, including entrepreneurship. The main goal of the model is to enable students to integrate their knowledge into their daily lives by establishing interdisciplinary connections and to develop an innovative perspective by linking science and engineering. In this direction, it is also aimed to strengthen entrepreneurial competencies by supporting life skills such as analytical thinking, teamwork, creativity, communication, and decision-making (MoNE, 2024). STEM education methods have increased in popularity over the last century and appear to be an advantageous teaching approach, especially for developing 21st-century skills (Yıldırım & Gelmez-Burakgazi, 2020).

STEM education refers to the integration of disciplines through inquiry-based and project-oriented approaches in contemporary education. Çevik, Şentürk, and Abdioglu (2019) define this trend as the leading example of multidisciplinary studies; Akgündüz et al. (2015 b) prioritise the use of educational approaches suitable for the 21st century in terms of preparing countries for Industry 4.0, students' success in international exams, and preparing for future professions at an early age. STEM, which has become a state policy, especially in the USA, contributes to both economic growth and the training of a qualified labour force by integrating knowledge of science and mathematics with technology and engineering, and by supporting applied learning (Aydeniz & Bilican, 2018; Bybee, 2013; Sanders, 2015).

The engineering design process enables students to systematically experience the stages starting from defining and analysing a problem to gathering information, developing ideas, planning, generating creative solutions, prototyping, testing, and, if necessary, optimising (Moore et al., 2014; NGSS Lead States, 2013; NRC, 2012). Dym, Little, Orwin, and Spjut (2009) define this process as a systematic method that requires reflection in which engineers design and evaluate products or schematics for systems, devices, and processes to meet the requirements of customers and users within various constraints. NASA (2011) defines the engineering design process as a cycle of repeated steps that guides a team of engineers in developing a new product or system and enables continuous improvement (Figure 1). Furthermore, integrating engineering design into educational programmes can be achieved through context integration (a pedagogical approach that supports science and mathematics concepts) or content integration (direct learning that includes both science/mathematics and engineering outcomes) (Moore & Smith, 2014).

In this study, the aim was to examine the effects of engineering-design-based STEM activities on students' entrepreneurship skills. Within the scope of the study, answers to the following research questions were sought.

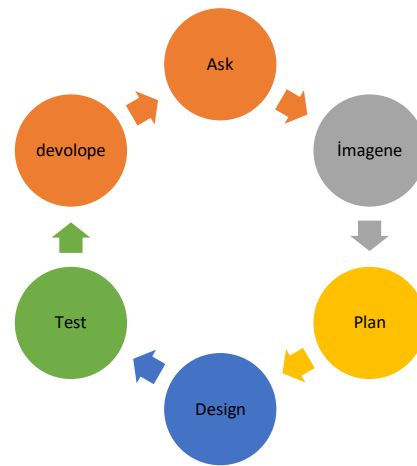


Figure 1 Engineering design cycle process (NASA, 2011)

- Do engineering design-based STEM activities affect students' science-based entrepreneurship skills?
- What are the students' views on the engineering design-based STEM education process?
- What are the students' views on the role of engineering design-based STEM activities in gaining science-based entrepreneurship skills?

2. METHOD

This research used a mixed-methods approach. Mixed-methods research is an approach that uses both quantitative and qualitative data, thereby facilitating a better understanding of the research problem (Creswell & Plano-Clark, 2023). The researcher first collects the first type of data and then uses the second type of data to provide supporting information. For example, in experimental studies, qualitative data are collected to inform the design of the intervention or to explain quantitative results (Creswell & Creswell, 2017). The study design is an embedded experimental design. In an embedded experimental design, one method is more dominant than the other. In other words, one data set serves as the foundation, while the other explains or supports it. In this model, quantitative techniques are prioritised, and qualitative data is considered secondary (Creswell & Plano Clark, 2007).

2.1 Participants

The present study was conducted with 50 seventh-grade students, selected through a purposive (convenience) sampling method. This approach involves selecting participants who are most readily accessible within the target population (Patton, 2005). Although convenience sampling is generally considered less rigorous than probability-based methods due to its limited capacity to represent the broader population, it was deemed appropriate for this study given its longitudinal nature and the fact that the researcher's own school served as the data collection site. Of the participants, 26 were assigned to the experimental group and 24 to the control group.

Participants were assigned to these groups using simple random sampling, a method in which each unit in the population has an equal probability of being selected. In practice, this involves drawing names at random from a predefined list (Çepni, 2010). Before implementing the intervention, a series of procedures was followed to determine the equivalence of the two groups.

2.2 Data Collection Tools

In the study, the "entrepreneurship scale for science course" was used to collect quantitative data, and a semi-structured interview guide was used to collect qualitative data. The "Entrepreneurship scale for science course" developed by Yolagiden and Bektaş (2021) used in the research consists of 24 items and is evaluated across three sub-dimensions (Self-regulation, Innovation, Self-efficacy). The scale is administered using 5-point Likert-type response options; thus, participants' scores range from 24 to 120. In addition, Cronbach's alpha coefficients for the scale (overall: 0.89; Self-regulation: 0.71; Innovation: 0.85; Self-efficacy: 0.75) indicate adequate reliability and validity.

The researcher prepared the semi-structured interview form. The interview forms were reviewed for content by three experts in science education (a professor, a lecturer, and a science teacher), and revisions were made in line with their expert opinions. In this context, sub-questions were added to some interview questions to obtain more detailed data. One interview question was removed because it was not appropriate for the class level. A language expert for

grammar also analysed the interview form, and grammatical errors were corrected based on the feedback provided.

2.3 Implementation process

During the research implementation, problem-based scenarios were prepared first (Table 1). In these scenarios, problem situations from daily life and those that students may encounter were presented. Then, a presentation on the problem-based learning method was given to the students. Afterwards, theoretical information about STEM education and the engineering design cycle was given. In the application phase, the prepared scenarios were first distributed to the students, who were asked to identify the problem situation in each scenario. At this stage, students identified the main and sub-problems mentioned in the scenario. Then, using the problem-based learning method, they collected information and developed ideas by conducting research into the problem's solution. According to the engineering design cycle, the experimental group students applied the steps of "ask, imagine, plan, design, test, and develop" in their respective groups. At the end of the process, they were enabled to market the products they produced based on the solution proposals they developed for the problem by introducing them in different environments. During implementation, they created three scenarios and nine entrepreneurial projects for each. In this context, students developed natural cleaning products to address the harms of chemical cleaning products; natural fertiliser; dog food based on the idea of recycling food waste; and alternative electrical

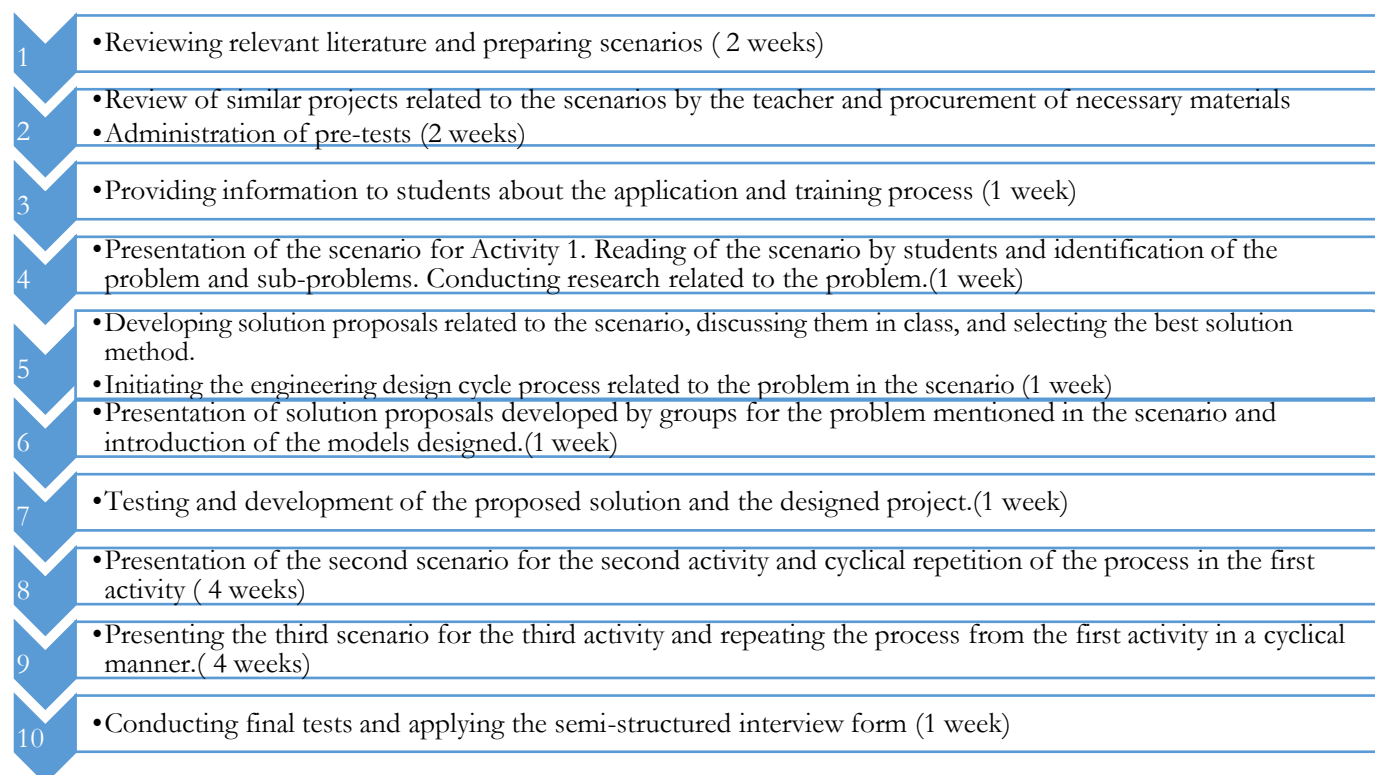


Figure 2 Processes carried out during the application process

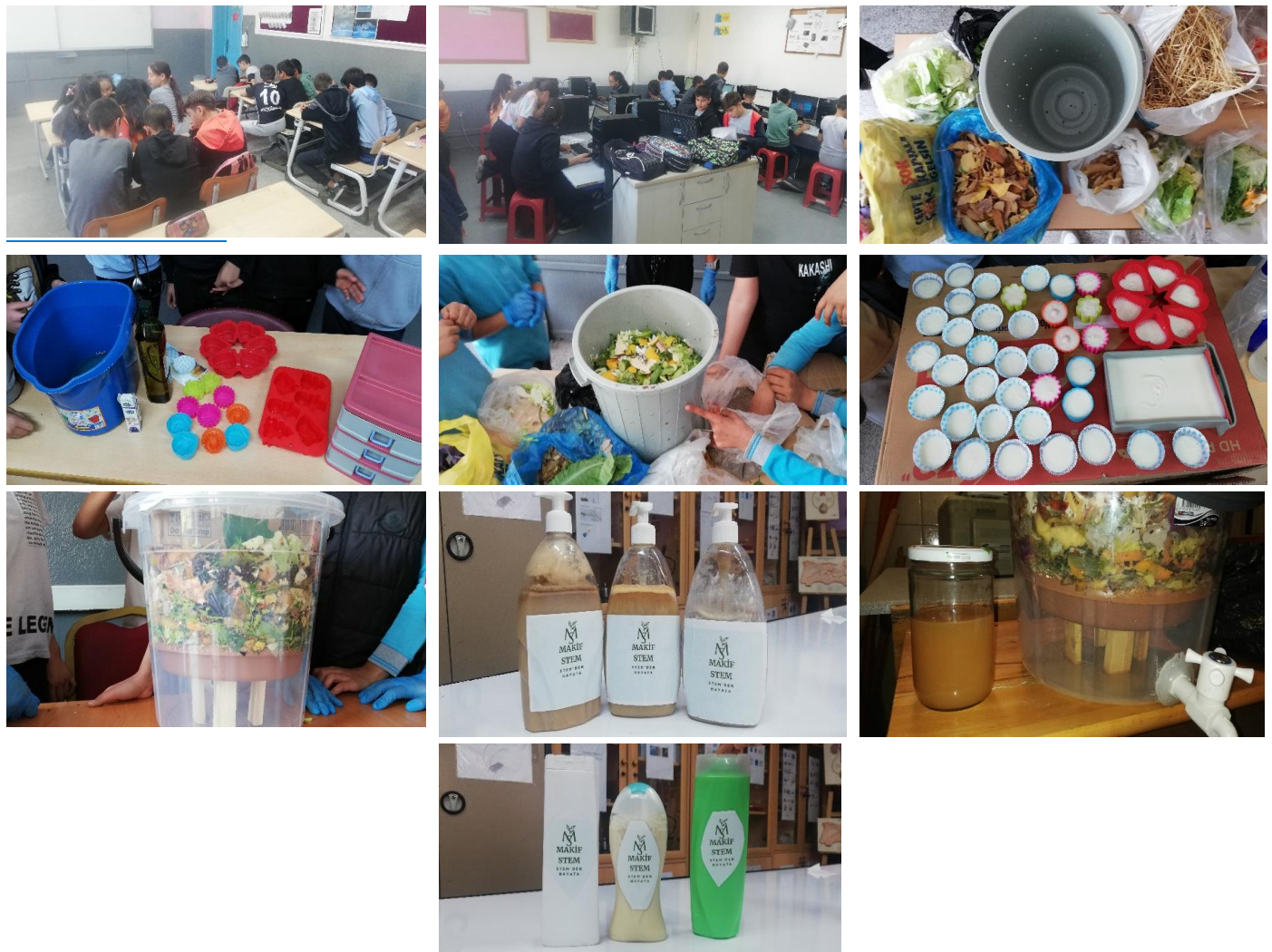


Figure 3 Products produced at the end of the application and an image from the promotion and marketing processes

Table 1 Implementation dimension of the research

Method	Group	Before the implementation process	Implementation process	After the implementation process
Quantitative Method	Experimental group	Science-Based Entrepreneurship Scale Pre-Test	Scenario-based and problem-based STEM activities	Science Based Entrepreneurship Scale Posttest
Quantitative Method	Control group	Science-Based Entrepreneurship Scale Pre-Test	Mathematics and Science Applications Course Curriculum	Science Based Entrepreneurship Scale Posttest
Qualitative Method	Experimental Group			The semi-structured interview form
Qualitative Method				

energy generation products where there is a need for electrical energy. Then, students designed logos for their products and created product brands. They presented their products to visitors at the school bazaar and made sales. Figure 2 shows processes carried out during the application process, while figure 3 depicts products produced at the end

of the application, and an image from the promotion and marketing processes.

2.4 Data Analyses

In this study, quantitative data collected during the research process were analysed using SPSS 22.0. The SPSS programme is used to compare groups or to show changes

in measurements taken at different times within a group. While analysing the quantitative data, analyses were conducted at both the whole-scale and sub-factor levels. To support the quantitative data and obtain detailed information on the reasons, qualitative data were collected through semi-structured interviews with the experimental group students. These qualitative data aimed to reveal students' entrepreneurial skills through the dimensions and themes of the measurement tools used. In light of different approaches in the literature, it was considered essential to describe the data and determine the themes; for this reason, the data were classified by descriptive analysis method by creating a conceptual framework, and the findings were determined and interpreted (Yıldırım & Şimşek, 2016). In analysing qualitative data, each participant was coded as S1, S2, S3, and so on.

The sub-problems of the study were addressed by comparing the pre-test scores of students in the experimental and control groups to determine whether their dependent variable levels were equal. An independent-samples t-test was performed on the science-based entrepreneurship scale. The results of the Levene test indicated that the variances were homogeneous and that there was no statistically significant difference between the experimental and control groups in academic achievement ($p = 0.15$). In the analysis, equality was established because there was no statistically significant difference between the groups.

2.5 Ethical Approval

The authors were contacted via e-mail regarding the scales used in the study, and the necessary permissions were obtained and used. The study was conducted in accordance with the decision of Erciyes University Social and Human Sciences Ethics Committee, dated 29.08.2023, and 339. For qualitative data, participants provided voluntary consent forms, and permission documents were obtained from their parents.

Table 2 Frequency information of experimental and control groups

	Frequency	Percent	Valid Percent	Cumulative Percent
Control group	24	48.0	48.0	48.0
Experimental group	26	52.0	52.0	100.0
Total	50	100.0	100.0	

Table 4 Normality test results of pre-test and post-test scores of Science-Based Entrepreneurship Scale of Experimental Group Students

	Kolmogorov-Smirnovb	Kolmogorov-Smirnovb	Kolmogorov-Smirnovb	Shapiro-Wilk	Shapiro-Wilk	Shapiro-Wilk
	Statistic	df	Sig.	Statistic	df	Sig.
Pre_Test	.125	26	.200*	.936	26	.11
Post Test	.153	26	.120	.957	26	.34

3. RESULTS

The research results are presented in two sections: quantitative and qualitative.

3.1. Quantitative Results

The numerical information regarding the study participants is presented in Table 2. The frequency and percentage values of the group distribution of the students participating in the study are presented in Table 2. Accordingly, 50 students participated in the study. Of these students, 24 (48.0%) were in the control group, and 26 (52.0%) were in the experimental group. The similarity of the distributions across groups indicates a suitable sample structure for comparative analyses.

The distribution of students participating in the study by group and gender is shown in Table 3. Of the 24 students in the control group, 13 (26.0%) were female, and 11 (22.0%) were male. In the experimental group, 12 (24.0%) of 26 students were female, and 14 (28.0%) were male. The gender distribution in the general sample is balanced, and both groups have similar proportions of female and male students.

Before proceeding to the predictive tests, it was examined whether the dependent variables were normally distributed. The statistical analyses indicated that the data were normally distributed. In this respect, it was observed that the skewness and kurtosis values ranged from -1 to +1. The Shapiro-Wilk normality test p-value was greater than 0.05, indicating that the data were normally distributed. Based on these results, parametric tests were used in predictive statistical analyses.

The results of the Shapiro-Wilk test regarding whether the Science-Based Entrepreneurship Scale (SBES) pre-test and post-test scores of the students in the experimental group fit the normal distribution are presented in Table 4. According to the Shapiro-Wilk test, the distributions of

Table 3 Gender distribution of the students participating in the study

	Frequency	Percent	Valid Percent	Cumulative Percent
Control Group	Woman 13	26.0	26.0	26.0
Control Group	Male 11	22.0	22.0	48.0
Experimental Group	Woman 12	24.0	24.0	72.0
Experimental Group	Male 14	28.0	28.0	100.0

Table 5 Normality test results of Control Group Students' Science-Based Entrepreneurship Scale Pre-test and Post-test scores

	Kolmogorov-Smirnov	Kolmogorov-Smirnov	Kolmogorov-Smirnov	Shapiro-Wilk	Shapiro-Wilk	Shapiro-Wilk
	Statistic	df	Sig.	Statistic	df	Sig.
Pre_Test	.14	24	.20*	.96	24	.39
Post Test	.13	24	.20*	.94	24	.16

Table 6 Science-based entrepreneurship scale pre-test descriptive statistics results of experimental and control group students

	Group	N	Mean	Std. Deviation	Std. Error Mean
Pre test	Kontrol	24	82.42	7.60	1.55
Pre test	Dency	26	85.46	7.21	1.41

pretest scores ($p = .11$) and posttest scores ($p = .34$) were not statistically significant ($p > .05$). These results indicated that both variables were normally distributed. Therefore, it was concluded that parametric tests could be used for the SBES scores of the experimental group.

The suitability of the Science-Based Entrepreneurship Scale (SBES) pre-test and post-test scores of the students in the control group for normality was evaluated using the Shapiro-Wilk test (Table 5). According to the test results, the distributions of pretest scores ($p = .39$) and posttest scores ($p = .16$) were not statistically significant ($p > .05$). These findings indicate that the SBES scores of the control group follow a normal distribution and support the use of parametric tests on these data.

Descriptive statistics related to the pre-test scores of the experimental and control group students' Science-Based Entrepreneurship Scale (SBES) are given in Table 6. While the control group's mean pretest score was 82.42 ($SD = 7.60$), the experimental group's mean pretest score was 85.46 ($SD = 7.21$). Although the two groups' averages were close, the experimental group's was slightly higher. This result indicates slight differences between the groups at baseline; however, to determine whether these differences are statistically significant, an unrelated-samples t-test should be applied.

The results of the independent-samples t-test comparing the Science-Based Entrepreneurship Scale (SBES) pre-test scores of the experimental and control group students are presented in Table 7. According to Levene's test, no significant difference in variance was found between groups ($p = .64 > .05$); therefore, the assumption of equal variance was met, and the analysis was interpreted accordingly. According to the t-test results, no statistically significant difference was found between the pre-test scores of the experimental and control groups ($t(48) = -1.45, p = .15 > .05$). This indicates that the Science-Based Entrepreneurship levels of both groups were similar before the intervention.

The results of the independent-samples t-test comparing the Science-Based Entrepreneurship Scale (SBES) pre-test scores of the experimental and control group students are presented in Table 7. According to Levene's test, no significant difference in variance was found between groups ($p = .64 > .05$); therefore, the assumption of equal variance was met, and the analysis was interpreted accordingly. According to the t-test results, no statistically significant difference was found between the pre-test scores of the experimental and control groups ($t(48) = -1.45, p = .15 > .05$). This indicates that the Science-Based Entrepreneurship levels of both groups were similar before the intervention.

The results of the independent-samples t-test comparing the Science-Based Entrepreneurship Scale (SBES) posttest scores of the experimental and control group students are presented in Table 8. Levene's test indicated equal variances ($p = .46 > .05$), so the t-test was conducted under the assumption of equal variances. As a result of the analysis, a significant difference was found between the posttest scores of the experimental and

Table 7 Independent samples t-test results of science-based entrepreneurship scale pre-test scores of experimental and control group students

	Levene's Test for Equality of Variances		t-test for Equality of Means		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Pre Test Equal variances assumed	.21	.64	-1.45	48	0.15	-3.04	2.09	-7.26	1.17
Pre Test Equal variances not assumed			-1.45	47.1	0.15	-3.04	2.10	-7.27	1.18

Table 8 Independent samples t-test results of science-based entrepreneurship scale post-test scores of experimental and control group students

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper	
Post Test	Equal variances assumed	.55	.46	-10.39	48	.00	-14.55	1.40	-17.37	-11.74
Post Test	Equal variances not assumed			-10.34	46.37	.00	-14.55	1.41	-17.39	-11.72

Table 9 Descriptive statistics results of science-based entrepreneurship scale sub-factors for the experimental group

		Mean	N	Std. Deviation	Std. Mean
1. Factor	Self-regulation pre-test	37.62	26	4.27	.84
	Self-regulation post-test	45.27	26	2.91	.57
2. Factor	Innovation pre-test	31.23	26	3.47	.68
	Innovation post-test	39.31	26	2.96	.58
3. Factor	Self_Efficacy pre-test	16.62	26	4.05	.79
	Self_Efficacy post-test	22.81	26	1.79	.35

Table 10 Dependent sample t-test results of science-based entrepreneurship scale sub-factors of the experimental group

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
1. Factor	Self-regulation Pre-test Self-regulation Post-test	-7.65	5.46	1.07	-9.86	-5.45	-7.16	25	.00
2. Factor	Innovation Pre-test Innovation post-test	-8.07	4.96	.97	-10.08	-6.07	-8.30	25	.00
3. Factor	Self-efficacy pre-test Self-efficacy post-test	-6.19	4.55	.89	-8.03	-4.35	-6.94	25	.00

control groups ($t(48) = -10.39, p < .005$). The experimental group's average score was approximately 14.55 points higher than the control group's. This finding shows that the science-based entrepreneurship education programme significantly improved students' entrepreneurship skills in the experimental group.

The descriptive statistics of the pre-test and post-test scores of the Science-Based Entrepreneurship Scale (SBES) sub-factors of the experimental group are given in Table 9. In the self-regulation factor, while the pre-test mean was 37.62 (SD = 4.27), the post-test mean was 45.27 (SD = 2.91). In the innovation factor, the pre-test mean was 31.23 (SD = 3.47) and the post-test mean was 39.31 (SD = 2.96). In the self-efficacy factor, while the pre-test mean was 16.62 (SD = 4.05), the post-test mean was 22.81 (SD = 1.79). These findings show that the students in the experimental group experienced a significant increase in

the sub-dimensions of the science-based entrepreneurship scale after the application.

A dependent-samples t-test was used to determine whether there were significant differences between the pre-test and post-test scores for the Science-Based Entrepreneurship Scale (SBES) sub-factors in the experimental group. (Table 10). In the self-regulation factor, a significant difference was found between the pre-test and post-test scores ($t(25) = -7.16, p < .005$). The mean difference was -7.65, and the post-test scores were significantly higher than the pre-test scores. Similarly, a significant difference was found in the innovation factor ($t(25) = -8.30, p < .005$), with a mean difference of -8.07. In the self-efficacy factor, a significant difference was found between pre-test and post-test scores ($t(25) = -6.94, p < .005$), with a mean difference of -6.19. These results show that the students in the experimental group demonstrated significant improvements in their skills and

perceptions in the sub-dimensions of the science-based entrepreneurship scale after the training.

The comparison of pre-test and post-test scores from the scale revealed that engineering design-based STEM activities led to a statistically significant increase in entrepreneurship skills ($p < 0.05$). Significant improvements were observed, especially in sub-dimensions such as creative thinking, risk-taking, self-confidence, leadership, motivation, and co-operation. This shows that STEM activities not only provide science or engineering knowledge, but also develop students' life skills such as generating solutions, developing ideas, implementing, and leading in the face of real-life problems. Based on the findings, the highest level of development is in the "creativity and innovation" dimension. This finding is directly related to the structure of engineering design-based STEM activities that allow students to develop original designs and use their imagination. In addition, the increase in the dimension of "self-confidence and determination" was also found to be significant. This can be interpreted as students developing in a learning environment where they can express their ideas, are given the right to trial and error, and making mistakes is included in the learning process.

3.2. Qualitative Results

Results obtained from students' opinions about the implementation process carried out with engineering design-based STEM activities.

In line with the opinions received from the students, the students' views on the process of implementing engineering design-based STEM activities were analysed and grouped into six meaningful themes.

Co-operation and Group Dynamics

Participants stated that they exhibited behaviours such as generating ideas, sharing tasks, and working together to reach a common goal during the projects. It was said that exchanging ideas within the group contributed to their understanding of different perspectives and strengthened their social relations. There are opinions that joint decision-making processes with group members are fun and producing together is satisfying. In this context, S3: "It was gratifying to work as a group to solve a problem." S6: "We first discussed our idea together, then we decided on our idea, and everyone took a task to do it." Moreover, S7: "We could not solve some things alone; it was easier when we thought together."

Creativity, Design, and Production Orientation

Students stated that they worked in a free environment to develop ideas, design products, and transfer these ideas into the application area in the STEM process. It was said that, thanks to the experimental structure of the process, it is possible to learn through trial-and-error methods, and that learning from mistakes is considered natural; thus, productivity increases. The students stated that they were able to express their own ideas freely, that they looked for

different solutions, and that they were more motivated when they made their ideas concrete. When the opinions about these expressions are analysed, S6: "We developed new ideas and designed our own product while doing projects." S4: "We tried different ideas, and finally we chose the best one." and S1: "I thought that the product we designed during the project would not work, but then it worked when we made some arrangements, and this made me happy."

Entrepreneurship Values and Motivational Development

Participants stated that during the engineering design-based STEM education process, they encountered the concept of entrepreneurship in ways they had not noticed before and internalised some values. In particular, they stated that affective gains such as perseverance, patience, not giving up, and determination came to the fore. Students began to define entrepreneurship not only as generating ideas, but also as defending, explaining, and realizing them. It was stated that the ways of coping with the difficulties they experienced in this process improved their intrinsic motivation and increased their confidence in their own potential. S4: "I think entrepreneurship is about not giving up and I have learnt this", S7: "I am no longer afraid of taking risks, I can take more risks", S2: "Thanks to this course, I can calculate money while developing a product, I work more planned and I use time well". S8: "..... I learnt to trust my own ideas." S10: "..... When I succeeded in something, I wanted to do more."

Self-confidence, Courage, and Emotional Development

The participants stated that they were initially shy about expressing opinions and speaking in the group; however, as the process progressed, they became more comfortable presenting ideas and gained self-confidence. S1: "I was hesitant at first, but I was no longer afraid of expressing my opinion." S9: "At first, I could not tell my ideas to my group mates, I thought it was ridiculous, but then I told my ideas because STEM means this", S4: "When I presented the project, I was thrilled that everyone liked it", S6: "When my friends in the group liked my idea and accepted to do that project, I was proud and wanted to find better ideas".

Connecting with Real Life and Social Awareness

Students stated that the problems they encountered in engineering design-based STEM activities that were associated with daily life attracted their attention, and the information they learned became meaningful. The students stated that mainly producing projects for the benefit of society motivated them, and they realised that learning is directly related to life. S5: "We learnt information that we can use in real life." S2: "It was very nice to do something useful for society." S6: "We also did a project for feeding animals in this course. Entrepreneurship is not only about earning money but also about doing something useful for society. With the project we did, we ensured that stray animals were fed." S7: "The activities we encountered in

the lesson were from real life; we also encountered them, so it was nice for me to do such projects".

Attitude and Participation

Students reported that engineering design-based STEM activities were both fun and instructive. The innovative nature of the process positively affected students' attitudes towards the course and increased their active participation. It was stated that the project-based learning environment attracted their attention differently from the ordinary course flow; thus, they internalised the information they learned and had the opportunity to apply it. In support of these findings, S2: "The process was very nice and fun.", S1: "In other lessons, we only solve questions or take notes, but in this lesson we did everything, we had more responsibility, but I enjoyed this situation". S9: " In this lesson, our teacher guided us, we did the rest of the things, group work was good even though it was sometimes difficult, I liked it". T 10: "This lesson was different from other lessons. I would like to teach other lessons in this way." T 3: "We both had fun and learnt while doing the projects in the lesson, this lesson was very productive for me".

Regarding the process carried out through engineering design-based STEM activities, Students stated that they exchanged ideas during group work, distributed tasks, and that working together supported both their social relations and learning processes. Design- and production-oriented activities provided students with the opportunity to develop ideas, learn through trial and error, and produce solutions, thereby increasing their creativity and productivity. The students who stated that they got to know entrepreneurship values more closely in the process indicated that they improved especially in skills such as risk-taking, determination, planning work, and financial thinking. In addition, the students said that their self-confidence increased as they participated in the activities, they expressed their ideas more easily in the group, and their confidence in their own potential was strengthened. The association of STEM applications with real-world problems drew students' attention and made the course more meaningful and functional. Students emphasised that the experiences of developing products that would provide social benefit motivated them, and they realised that learning is related to life. Finally, students stated that these activities were fun, instructive, and interesting, unlike in other courses; that they actively participated in the process; and that taking responsibility in this process improved them.

Results obtained from students' opinions on the effects of engineering design-based STEM activities on entrepreneurial skills.

Based on the data obtained from the students, the effects on entrepreneurship skills are presented as follows: risk-taking, creativity and innovation, time management,

financial management, co-operation and teamwork, perseverance, presentation, effective communication, and problem-solving.

Risk Taking

The students stated that they did not hesitate to try different solutions along the way and that they took the risk of making decisions in situations where the outcome was unknown. They stated that making mistakes did not prevent them from learning and that they were open to the trial-and-error process. In this context, S3: "We tried something different this time, we did not know whether it would work or not, but we did it anyway." S7: "At first I was afraid of making mistakes, but then I realised that making mistakes was not a bad thing." S9: "We tried a different method, it did not work at first, but then it worked. I am glad we tried it." They made such statements.

Creativity and Innovation

The students stated that they produced ideas that had not been used before and developed their own methods during the activity. They indicated that they worked on out-of-the-ordinary solutions and sought originality in their designs. In this regard, S2: "No one had ever done the idea in our minds before; we were the first to try it." S5: "It was very fun to make different designs, I always came up with new ideas." S6: "Producing our own project and developing new ideas gave me self-confidence." They used these expressions.

Time Planning

The students stated that they put things in order, made plans, and tried to use time effectively to complete the tasks within the given time. S4: "We had little time, so I learnt that we should do everything in order." S8: "When we could not use the time well, we could not complete some things, and this was a lesson for us." S9: "We planned what to do every day, then things were easier."

Financial Management

Regarding financial management, one of the basic skills of entrepreneurship, the students stated that they had to work with limited resources, paid close attention to economic choices in material selection, and tried to act within the budget. S1: "The materials were expensive, so we tried to find cheaper ones." S7: "Even if we have money, we should not waste it." S10: "We were able to do the same job by using the most affordable part." They included the following statements.

Co-operation

The students stated that they distributed tasks during group work, worked cooperatively with their friends, and progressed by making joint decisions. In this context, S3: "Everyone had a task, everything was easier when we worked together." S4: "I could not do some things alone; I cooperated with my friends." S8: "It was necessary to produce something by brainstorming, explaining our ideas, and finally agreeing."

Not giving up

The students stated that they did not stop working in case of failure; they tried again and continued the process until they achieved the result. S7: "We failed in our first attempt, but we did not give up; we tried again." S9: "We finally did it because we did not give up." S10: "We could not achieve the result we wanted in one of our projects, but we made some changes and redesigned it, and then we were successful, which made me happy."

Making a Presentation

The students stated that they had the opportunity to express their ideas to others at the end of the project, that they were excited at the beginning of the presentations, but that they got used to it over time, and were able to express themselves. S5: "In the preliminaries, I was excited while making presentations in our group or in the classroom, but then I got used to it." S7: "It was very nice to tell people about the products we obtained from our projects." S8: "When people saw what we did, they liked it. It was nice to tell them about our project."

Effective Communication

The students stated that they expressed their ideas clearly, that communication within the group positively affected the working process, and that they made decisions by listening to their friends. S1: "When I listened to my friend, I understood what he actually meant, and we decided accordingly." S4: "Everyone expressed their opinions, then we reached a common decision." S7: "When we communicate well, things progress faster." They expressed their opinions as follows.

Problem-Solving Skills

The students stated that they tried to develop solutions to the technical or structural problems they encountered; they analysed the issues, focused on identifying their causes, and were involved in the solution process. S8: "When we encountered a problem, we first did research about it, we looked for similar solutions". S2: "We misconnected the circuit. We found where we made a mistake and corrected it." S6: "When there was a problem, we first thought about why it happened, then we looked for a solution." S9: "When a problem arose, we tried to solve it without panicking."

In the descriptive analysis of the entrepreneurial skills of students who participated in engineering design-based STEM activities, it was determined that these activities improved various sub-dimensions of students' entrepreneurial skills. The students stated that they did not hesitate to try new ideas during the process and that they made decisions and put them into practice even if there was a possibility of making mistakes. They stated that they developed original ideas during the activities, tried solution methods that had not been used before, and that this situation increased their creativity. In terms of time management, the students stated that they prioritised tasks and tried to act in a planned manner to complete their

assignments on time. In addition, they indicated that they had to work with limited resources, so they carefully selected budget-friendly, functional materials and avoided unnecessary expenditures. Regarding group work, the students stated that they worked in co-operation with their teammates, exchanged ideas, and made joint decisions. Despite the difficulties encountered, they continued to look for solutions without giving up, demonstrating perseverance. The students also stated that their ability to present and explain their ideas to others improved; they felt more comfortable during the presentation and expressed themselves better. Finally, they indicated that they improved their ability to communicate effectively and to have mutual understanding during the activity, that they tried to produce solutions together when they encountered technical or organisational problems, and that this improved their problem-solving skills.

In this study, in line with students' opinions on engineering design-based STEM activities, it was concluded that these activities were practical for developing students' entrepreneurial skills and for fostering positive changes in their attitudes towards the learning process. It was determined that students established effective co-operation during group work, exchanged ideas, and worked together toward a common goal. In the design and production processes that supported creativity, students developed original ideas, transformed them into products, and thus improved their problem-solving, decision-making, and innovation skills. It was understood that the process contributed to the internalisation of entrepreneurship values (such as self-confidence, determination, risk-taking, financial planning, and social benefit) and students integrated these values into their own learning experiences. In addition, it was concluded that STEM applications contributed to students' affective development, strengthened their self-efficacy beliefs, and made learning meaningful by connecting it to real life. In this context, it can be said that engineering design-based STEM activities are an effective method for providing student-centred, production-oriented, and interactive learning environments by integrating with entrepreneurship education.

The thematic analysis derived from the interviews with the students both supports the quantitative findings and deepens the layers of meaning. Students stated that STEM processes develop not only academic but also social and affective skills.

Self-confidence and Determination: Students' statements such as "I used to hesitate, but now I speak my mind" or "I learnt to correct my mistakes and move on" point to the development of self-confidence. These statements coincide with the increase in self-confidence determined by the scale.

Creativity and Innovation: Students reported generating original ideas in STEM, with comments such as "I made

my own design" and "I found my own solution, not someone else's". This supports the development of creative thinking skills.

Motivation and Perseverance: The fact that the project process was "enjoyable and meaningful" increased students' intrinsic motivation. Students' expressions such as "I did not give up, I tried again" reveal the effect of STEM processes on the determination to learn.

Co-operation and Leadership: It is understood from the comments of the students, such as "we made decisions together", "we valued everyone's opinion", that the skills of leadership, taking responsibility, and respecting the opinions of others were developed in group work. This also supports the quantitative increase in co-operation and communication skills.

4. CONCLUSION AND DISCUSSION

This study aimed to examine the effects of engineering-design-based STEM activities on the entrepreneurial skills of secondary school students using both quantitative and qualitative data. Within the scope of the research, both quantitative data obtained from the entrepreneurship skills scale and qualitative findings obtained from student interviews were evaluated together. In this section, the findings are analysed as a whole, and both the effectiveness of the practices is discussed, and the results are compared with the related literature.

4.1 Quantitative results and discussion on Entrepreneurship Skills

The comparison of pre-test and post-test scores from the scale revealed that engineering design-based STEM activities led to a statistically significant increase in entrepreneurship skills ($p < 0.05$). Significant improvements were observed, especially in sub-dimensions such as creative thinking, risk-taking, self-confidence, leadership, motivation, and co-operation. This shows that STEM activities not only provide science or engineering knowledge, but also develop students' life skills such as generating solutions, developing ideas, implementing, and leading in the face of real-life problems. Based on the findings, the highest level of development is in the "creativity and innovation" dimension. This finding is directly related to the structure of engineering design-based STEM activities that allow students to develop original designs and use their imagination. In addition, the increase in the dimension of "self-confidence and determination" was also found to be significant. This can be interpreted as students developing in a learning environment where they can express their ideas, are given the right to trial and error, and making mistakes is included in the learning process.

4.2 Conclusions and discussion on qualitative findings in entrepreneurship skills

In this study, in line with students' opinions on engineering design-based STEM activities, it was concluded that these activities were practical for

developing students' entrepreneurial skills and for fostering positive changes in their attitudes towards the learning process. It was determined that students established effective co-operation during group work, exchanged ideas, and worked together toward a common goal. In the design and production processes that supported creativity, students developed original ideas, transformed them into products, and thus improved their problem-solving, decision-making, and innovation skills. It was understood that the process contributed to the internalisation of entrepreneurship values (such as self-confidence, determination, risk-taking, financial planning, and social benefit) and students integrated these values into their own learning experiences. In addition, it was concluded that STEM applications contributed to students' affective development, strengthened their self-efficacy beliefs, and made learning meaningful by connecting it to real life. In this context, it can be said that engineering design-based STEM activities are an effective method for providing student-centred, production-oriented, and interactive learning environments by integrating with entrepreneurship education.

4.3 Integrating Qualitative Findings with Quantitative Results

The thematic analysis derived from the interviews with the students both supports the quantitative findings and deepens the layers of meaning. Students stated that STEM processes develop not only academic but also social and affective skills.

Self-confidence and Determination: Students' statements such as "I used to hesitate, but now I speak my mind" or "I learnt to correct my mistakes and move on" point to the development of self-confidence. These statements coincide with the increase in self-confidence determined by the scale.

Creativity and Innovation: Students reported generating original ideas in STEM, with comments such as "I made my own design" and "I found my own solution, not someone else's". This supports the development of creative thinking skills.

Motivation and Perseverance: The fact that the project process was "enjoyable and meaningful" increased students' intrinsic motivation. Students' expressions such as "I did not give up, I tried again" reveal the effect of STEM processes on the determination to learn.

Co-operation and Leadership: It is understood from the comments of the students, such as "we made decisions together", "we valued everyone's opinion", that the skills of leadership, taking responsibility, and respecting the opinions of others were developed in group work. This also supports the quantitative increase in co-operation and communication skills.

The findings align with many studies that argue that STEM-based education practices support the development of entrepreneurial skills in students. For example, Bybee

(2013) states that STEM education prepares students not only to be scientists, but also to be problem-solving, leading, and innovative individuals. Similarly, MoNE (2018) emphasises that STEM activities are effective in equipping students with 21st-century skills. The literature indicates that STEM activities enable students to develop design and creativity skills (Zhanova, 2017). In his study with secondary school students, Konuş (2019) concluded that entrepreneurship and STEM tendencies are high, and that there is a moderate relationship between students' entrepreneurship tendency and STEM attitudes. Deveci and Seikkula-Leino (2016) stated that, in the development of entrepreneurial skills, it is of great importance to create a reasonable competitive environment in which students help and inspire one another, and cooperation is possible. Evcim (2021) found that STEM activities significantly improved students' entrepreneurship skills. Şirin (2020) found that STEM activities positively affected the entrepreneurship skills of 7th-grade students in his study conducted with secondary school students. Sarı & Yazıcı (2019) found that STEM activities statistically significantly increased students' entrepreneurship skills. Pekbay, Saka, and Kaptan (2020), in their study aimed at evaluating STEM activities prepared according to the engineering design process, found that secondary school students perceived this process as educational and fun. In the same study, they expressed positive opinions, such as that the STEM process supports group work and provides an environment for thinking and working like an engineer. Still, they also noted adverse effects on material supply, time management, and group work during the study. English, King & Smeed (2017), in their research on STEM education integrated with engineering design for secondary school students, found that students actively participated in the process and developed 21st-century skills. Fan & Yu (2017) reported positive effects of the integrative STEM education approach, based on their study on the effectiveness of integrating STEM in engineering design practices with high school students. Shahin, Ilic, Gonsalvez, and Whittle (2021) found, in a study of 193 female students, that STEM-focused entrepreneurship education positively affected students' perceptions of entrepreneurship. When the literature was examined, researchers stated that the engineering process supports learning by doing and experiencing; design-based tasks motivate students, enhance retention, and offer an inquiry-based approach. They also noted that these practices contribute to the development of creative and productive individuals with advanced problem-solving skills, have a positive effect on the development of 21st-century skills, and that the materials developed are remarkable and motivating (Aydın & Karşı-Baydere, 2023; Capobianco & Rupp, 2014; Guzey, Moore & Harwell, 2016; Hacıoğlu, Yamak & Kavak, 2017; Sarı & Yazıcı, 2019).

4.4 Recommendations

This research revealed that engineering-design-based STEM activities play an essential role in developing entrepreneurial skills among secondary school students. Based on the research findings, the following recommendations were developed:

Suggestions for Teachers and Practitioners

All branch teachers, especially science teachers, should be informed about STEM-based activities, and these practices should be integrated into in-class and extracurricular activities. In particular, practices based on the engineering design cycle support the development of entrepreneurial skills.

While planning STEM activities, teachers should clearly identify learning objectives that develop entrepreneurial skills (self-confidence, creativity, leadership, cooperation, decision-making, etc.). In this way, practices will become both interdisciplinary and skill-based.

Students develop the ability to cope with the difficulties they encounter in STEM processes. For this reason, teachers should provide guidance to facilitate the process and turn mistakes into learning opportunities.

Suggestions for Educational Administrators and Policy Developers

Integration of Entrepreneurship Skills into the Curriculum: Secondary school curricula should include activities that clearly define entrepreneurship skills and link them to STEM practices. In this context, STEM education should be seen not only as the teaching of scientific knowledge but also as a means of gaining 21st-century life skills.

Teachers should be provided with practical in-service training on the engineering design process, STEM education, project-based learning, and entrepreneurship skills. Training programmes should include not only information transfer but also workshops and practical scenarios.

To implement STEM activities sustainably, STEM workshops should be established in schools, and the support materials teachers need should be provided. A lack of resources may prevent some students from participating sufficiently in entrepreneurship processes.

Suggestions for Researchers

Conducting Research at Different Age Levels: This research is limited to secondary school students. To monitor the development of entrepreneurial skills, it is recommended that similar studies be conducted at the primary and high school levels.

Longitudinal studies should be conducted to examine the durability of STEM-based practices' effects on entrepreneurship skills.

Entrepreneurial skills are shaped not only in the school environment but also through interactions with family and the broader social environment. Therefore, the impact of

STEM projects with family involvement on students should be investigated.

In future studies, how STEM activities can support subtypes such as social entrepreneurship and environmental entrepreneurship can be examined in detail.

REFERENCES

- Achor, E. E., & Wilfred-Bonse, K. (2013). The need to integrate entrepreneurship education into science education teachers' curriculum in Nigeria. *Journal of Science and Vocational Education (JSVE)*, 7.
- Ağca, V., & Yumuşakipek, H. D. (2015). Günümüzde girişimcilik trendini yükselten güçler [The forces driving the entrepreneurial trend today]. *Girişimcilik: Temel Kavramlar, Girişimcilik Türleri, Girişimcilikte Güncel Konular*, Editör: Erdoğan Kaygın ve Bülent Güven, *Siyah İnci Yayınları*, 11-33.
- Akgündüz, D., Aydeniz, M., Çakmakçı, G., Çavaş, B., Çorlu, M. S., Öner, T., & Özdemir, S. (2015). *STEM education in Turkey: Report*, İstanbul: Scala Basım.
- Aydeniz, M., & Bilican, K. (2018). The impact of engagement in STEM activities on primary preservice teachers' conceptualisation of STEM and knowledge of STEM pedagogy. *Journal of Research in STEM Education*, 4(2), 213-234.
- Aydın, E., & Baydere, F. K. (2023). The Effects of the Activities Developed According to the Engineering Design Process on the Subject of "Simple Machines" on 8th Grade Students' Conceptual Understanding and Scientific Process Skills. *IBAD Journal of Social Sciences*, (14), 121-154.
- Aygün, S. S., Atalay, N., Kılıç, Z., & Yaşar, S. (2016). Development of 21st-century skills competence perceptions scale for pre-service teachers: Validity and reliability study. *Journal of Pamukkale University Faculty of Education*, 40(40), 160-175.
- Bybee, R. W. (2010). *The teaching of science: 21st century perspectives*. NSTA press.
- Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*.
- Capobianco, B. & Rupp, M. (2014). STEM teachers' planned and enacted attempts to implement engineering design-based instruction. *School Science and Mathematics*, 114(6), 258-270.
- Creswell, J. W., & Clark, V. P. (2007). *Mixed methods research*. Thousand Oaks, CA.
- Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.
- Creswell, J. W., & Plano Clark, V. L. (2023). Revisiting mixed methods research designs twenty years later. *Handbook of mixed methods research designs*, 1(1), 21-36.
- Çelik, A. (2018). *Entrepreneurship with informatics: A case study of 5th grade students' production with informatics in design-oriented improvisation activity*.
- Çepni, S. (2010). *Introduction to research and project studies*. Trabzon.
- Çevik, M., Şentürk, C., & Abdioğlu, C. (2019). *From STEM to STEM+*. Educated Book.
- Deveci, İ. (2016). *Development, implementation and evaluation of entrepreneurship education modules integrated with science curriculum (5-8)* (Doctoral dissertation, Bursa Uludağ University (Turkey)).
- Deveci, İ., & Konus, F. Z. (2022). The predictive power of Turkish middle school students' entrepreneurial competencies on STEM attitudes. *The Journal of Entrepreneurship*, 31(2), 425-457.
- Deveci, İ., & Seikkula-Lein, J. (2016). Finnish Science Teacher Educators' Opinions about the Implementation Process Related to Entrepreneurship Education. *Electronic Journal of Science Education*, 20(4), 1-20.
- Dym, C. L., Little, P., Orwin, E. J., & Spjut, R. E. (2009). The design process. *Engineering Design: A project-Based Introduction*, 22.
- English, L. D., King, D., & Smeed, J. (2017). Advancing integrated STEM learning through engineering design: Sixth-grade students' design and construction of earthquake-resistant buildings. *The Journal of Educational Research*, 110(3), 255-271.
- European Commission. (2013). Commission implementing regulation (EU) no. 485/2013 of 24 May. *Official Journal of the European Union*, 56, 12-26. <https://doi.org/10.2903/j.efsa.2013.3067>
- European Commission. (2004). *Action plan: The European agenda for entrepreneurship*. (<https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52004DC0070&from=EN>) Retrieved 18.03.2025
- European Commission (2008). *"Think Small First" A "Small Business Act" for Europe*. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52008DC0394&from=en> (Date of access: 18.03.2025)
- European Commission. (2012). *At the crossroads. Annual report on small and medium-sized enterprises in the EU, 2011/12* on http://ec.europa.eu/enterprise/policies/sme/facts-figures-analysis/performance-review/files/supporting-documents/2012/annual-report_en.pdf (Accessed 20.03.2025).
- Evcim, İ. (2021). *Investigation of the effect of developing the force and energy unit with STEM integration in science course on students' critical thinking skills and entrepreneurship competencies*. Yıldız Technical University.
- Fakharzadeh, A. (2012). Development of entrepreneurial attitude in Iranian elementary literature textbooks. *Journal of Entrepreneurship Education*, 15, 49.
- Fan, S. C., & Yu, K. C. (2017). How an integrative STEM curriculum can benefit students in engineering design practices. *International Journal of Technology and Design Education*, 27, 107-129.
- Fayolle, A., & Gailly, B. (2008). From craft to science: Teaching models and learning processes in entrepreneurship education. *Journal of European industrial training*, 32(7), 569-593.
- Ferrante, F. (2005). Revealing entrepreneurial talent. *Small Business Economics*, 25, 159-174.
- Florin, J., Karri, R., & Rossiter, N. (2007). Fostering entrepreneurial drive in business education: An attitudinal approach. *Journal of management education*, 31(1), 17-42.
- Graduates, D. E. (2008). *Putting entrepreneurship at the centre of higher education*. September 2008. Published by NESTA.
- Hacıoğlu, Y., Yamak, H. & Kavak, N. (2017). The opinions of prospective science teachers regarding STEM education: the engineering design-based science education. *GED/ GAGGED*, 37(2), 649-684.
- Hisrich, R. D., & Peters, M. P. (1989). Views of Trade Activity with the Soviet Union and China by US Manufacturers. *Journal of Global Marketing*, 2(2), 53-73.
- İşcan, Ö. F., & Kaygın, E. (2011). A research to determine the entrepreneurial tendencies of university students as potential entrepreneurs. *Journal of Organisation and Management Sciences*, 3(2), 275-286.
- Konus, F. Z. (2019). *Predicting the entrepreneurial tendencies of seventh and eighth grade secondary school students' STEM attitudes* (Master's thesis, Graduate School of Natural and Applied Sciences).
- Kurnaz, S. (2017). *A research in Orhangazi district of Bursa province to determine the entrepreneurship levels of students in Anatolian high schools that offer and do not offer accounting education* (Master's thesis, Institute of Social Sciences).
- MONE (2013). Primary Education Institutions (Primary and Secondary Schools) Science Course (Grades 3, 4, 5, 6, and 7) Curriculum. Ministry of National Education, Board of Education and Discipline Presidency, Ankara.
- MONE (2018). Primary Education Institutions (Primary and Secondary Schools) Science Course (3, 4, 5, 6, and 7th Grades) Curriculum. Ministry of National Education, Board of Education and Discipline Presidency, Ankara.
- MONE (2018). MEB 2023 vision. http://2023vizyonu.meb.gov.tr/doc/2023_EGITIM_VIZYON_U.pdf. (Date of access: 12.03.2025)
- MEB (2024). Primary Education Institutions (Primary and Secondary Schools) Science Course (Grades 3, 4, 5, 6, and 7) Curriculum.

- Ministry of National Education, Board of Education and Discipline Presidency, Ankara.
- Mercan Hbk, K. (2014). *Analysis of the subjects in which engineering-design method can be applied in secondary school 6th, 7th, 8th grade science and technology curriculum: Preparing alternative energy sources teaching materials*. *Erciyes University Institute of Educational Sciences (Master's Thesis)*. 1, 75.
- Miles, M. B., & Huberman, A. M. (1984). Drawing valid meaning from qualitative data: Toward a shared craft. *Educational researcher*, 13(5), 20–30.
- Moore, T. J., & Smith, K. A. (2014). Advancing the state of the art of STEM integration. *Journal of STEM Education: Innovations and Research*, 15(1), 5.
- Moore, T. J., Stohlmann, M. S., Wang, H. H., Tank, K. M., & Roehrig, G. H. (2014). Implementation and integration of engineering in K-12 STEM education. In J. Strobel, S. Purzer, & M. Cardella (Eds.), *Engineering in precollege settings: Research into practice*. West Lafayette, IN: Purdue Press.
- Morrison, A. (2000). Entrepreneurship: what triggers it?. *International Journal of Entrepreneurial Behaviour & Research*, 6(2), 59–71.
- National Aeronautics and Space Administration. (2011). *Beginning engineering, science and technology educator guides: An educator's guide to the engineering design process grades 6-8*. Retrieved from https://www.nasa.gov/pdf/630754main_NASAsBESTActivityGuide6-8.pdf (Access date: 14.03.2025).
- National Research Council [NRC]. (2012). *A Framework for k-12 science education: practices, crosscutting concepts, and core ideas*. Washington DC: The National Academic Press.
- NGSS Lead States. (2013). *Next generation science standards: state by state*. Washington, DC: The National Academies Press.
- zcan, E. (2019). *The effect of the socio-scientific argumentation method on students' levels of associating knowledge with daily life, entrepreneurship, and attitudes towards sustainable science* (Doctoral dissertation, Dokuz Eylul Universitesi (Turkey)).
- P21. (2009). *P21 Framework Definitions. Partnership For 21st Century Skills (P21)*, December 2009. Accessed online at : <http://www.21stcenturyskills.org> on 15 July 2025.
- Patton, M. Q. (2005). *Qualitative Research*. New York: John Wiley & Sons, Ltd.
- Pekbay, C., Saka, Y., & Kaptan, F. (2020). Secondary school students' views on activities prepared based on STEM education approach: Green engineering activities. *Journal of Inonu University Faculty of Education*, 21(2), 840-857.
- Prajapati, R. K., Sharma, B., & Sharma, D. (2017). Significance of life skills education. *Contemporary Issues in Education Research*, 10(1), 1–6.
- Rae, D., Martin, L., Antcliff, V., & Hannon, P. (2010, November). The 2010 survey of enterprise and entrepreneurship in higher education. In *33rd ISBE Conference* (pp. 3–4).
- Sanders, M. (2015). *Integrative STEM education: A more robust explanation*.
- Sarı, U., & Yazıcı, Y. Y. (2019). Science teachers' views on science and engineering applications. *International Journal of Social Sciences and Education Research*, 5(2), 157-167.
- Selcen Guzey, S., Harwell, M., Moreno, M., Peralta, Y., & Moore, T. J. (2017). The impact of design-based STEM integration curricula on student achievement in engineering, science, and mathematics. *Journal of Science Education and Technology*, 26, 207–222.
- Shahin, M., Ilic, O., Gonsalvez, C., & Whittle, J. (2021). The impact of a STEM-based entrepreneurship programme on the entrepreneurial intention of secondary school female students. *International Entrepreneurship and Management Journal*, 17(4), 1867–1898.
- Shane, S., & Venkataraman, S. (2000). The promise of entrepreneurship as a field of research. *Academy of management review*, 25(1), 217–226.
- Soutaris, V., Zerbinati, S. & Al-Lahan, A., (2007). Do entrepreneurship programmes raise entrepreneurial intention of science and engineering students? The effect of learning, inspiration and resources. *Journal of Business Venturing*, 22:566-591, 2007.
- Stevenson, H. H., & Jarillo, J. C. (2007). *A paradigm of entrepreneurship: Entrepreneurial management*. In *Entrepreneurship: Concepts, theory and perspective* (pp. 155–170). Berlin, Heidelberg: Springer Berlin Heidelberg.
- Şirin, E. (2020). *The effect of entrepreneurship-focused STEM activities on 7th grade students' entrepreneurship skills and STEM attitudes* (Master's thesis, Institute of Educational Sciences).
- Turiman, P., Omar, J., Daud, A. M., & Osman, K. (2012). Fostering the 21st-century skills through scientific literacy and science process skills. *Procedia-Social and Behavioural Sciences*, 59, 110–116.
- TBİTAK. *National Science and Technology Policies 2003-2023 Strategy Paper*, 19th ed.; TBİTAK: Ankara, Turkey, 2016; pp. 1–137.
- TSİAD (2011). *Vizyon 2050 Turkey Report*, Date of access: 15 March 2025; http://www.tusiad.org.tr/_rsc/shared/file/vizyon-2050-rapor.pdf.
- Ursavaş, N., & Karal, E. (2019). Science Teachers' Thoughts on Life Skills and Their Relevance to Science Outcomes. *Journal of Mediterranean Eđitim Arastirmalari*, 13(30), 246-269.
- Wilson, F., Kickul, J., & Marlino, D. (2007). Gender, entrepreneurial self-efficacy, and entrepreneurial career intentions: Implications for entrepreneurship education. *Entrepreneurship theory and practice*, 31(3), 387–406.
- Wilson, K. E. (2008). Entrepreneurship education in Europe. Entrepreneurship and higher education.
- World Economic Forum. (2009). Educating the next wave of entrepreneurs: Unlocking entrepreneurial capabilities to meet the global challenges of the 21st century. Geneva, Switzerland: World Economic Forum. (Retrieved 14 March 2025). <https://www.weforum.org/publications/world-economic-forum-annual-meeting-2009/>
- Yıldırım, A. and Şimşek, H. (2016). *Qualitative Research Methods in Social Sciences* (Expanded 10th Edition). Ankara: Seçkin Publishing.
- Yıldırım, H., & Gelmez-Burakgazi, S. (2020). A research on studies on STEM education in Turkey: Meta-synthesis study. *Pamukkale University Journal of Faculty of Education*, 50, 291-314. doi: 10.9779/paufed.590319
- Yolagiden, C., & Bektas, O. (2021). Development of Entrepreneurship Scale for Science Course: Validity and Reliability Study. *Afyon Kocatepe University Journal of Social Sciences*, 23(4), 1349–1365.
- Zhbanova, K. S. (2017). How the arts standards support STEM concepts: A journey from STEM to STEAM. *Journal of STEM Arts, Crafts, and Constructions*, 2(2), 1.