

Engineering Design-Based Thematic Activities: An Investigation of Pre-Service Science Teachers' Entrepreneurship Mindsets

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Abstract: The purpose of this study is to examine changes in pre-service science teachers' entrepreneurship mindsets during engineering design-based activities. A holistic single-case study was used in the study. Twenty-eight pre-service teachers carried out engineering design-based activities (five weeks, 20 hours) in the science teaching laboratory practices course. The pre-service teachers' use of Entrepreneurship Mindsets (EM) in solving the water pollution problem during engineering design-based activities was examined in this study. Data were collected via engineering design challenge worksheets and public service announcements. The data were analyzed with the Extended KEEN Student Outcomes (eKSOs) rubric. Frequency tables were created in line with the sub-dimensions of EM (curiosity, connections, creating value, communication, character, and collaboration). As a result of the research, it was found that the pre-service teachers mostly used curiosity, connections, and creating value during the water treatment and wastewater assessment plant design process. Engineering is an important context for the development of EM as it creates various contexts that contribute to the development of these mindsets in pre-service science teacher education.

Science Insights Education Frontiers 2022; 11(2):1531-1549.

Doi: 10.15354/sief.22.or050

How to Cite: Kiyici, G., Canbazoğlu Bilici, S., Yamak, H., Kavak, N. (2022).
Engineering design-based thematic activities: An investigation of pre-service

science teachers' entrepreneurship mindsets. *Science Insights Education Frontiers*, 11(2):1531-1549.

Keywords: Pre-service Science Teacher, Engineering Design-Based Thematic Activities, Entrepreneurship Mindsets (EM)

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Conflict of Interests: None.

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Introduction

DUE to global problems such as population growth and climate change, individuals frequently encounter complex problems in their daily lives. To solve these problems, there is a need to use interdisciplinary approaches that remove the traditional barriers between disciplines instead of focusing on knowledge about a single discipline (Wei & Chen, 2020). Curricula in the fields of physics, chemistry, biology, and engineering are based on an interdisciplinary process that covers scientific knowledge and ways to develop scientific knowledge (Nesmith & Cooper, 2019). In Science, Technology, Engineering, and Mathematics (STEM) education, real-life problems such as social, cultural, political, economic, and environmental issues are solved with the transdisciplinary integration of disciplines (Hoffmann-Riem et al., 2008). Engineering plays an important role in the transformation of knowledge into a product, skill, or innovative invention in STEM education. The role of engineering in STEM education is emphasized in the framework of K-12 education published by the American National Research Council (National Research Council [NRC], 2013). According to the report entitled “Engineering in K-12 Education: Understanding its Status and Improving its Prospects”, engineering should be taught to K-12 students. Students need to understand what engineers do at school and they need to learn about engineering as a career. Engineering education in schools increases students’ (i) understanding of science and mathematics, (ii) awareness of engineering, (iii) understanding of engineering by engaging in the engineering design process, (iv) willingness to pursue engineering as a career, and (v) technological literacy (Katehi et al., 2009).

Engineering design-based activities in STEM education are carried out in real-world contexts (Moore et al., 2014). These activities enable students to approach problems from a transdisciplinary perspective (Hoffmann-Riem et al., 2008; Takeuchi et al., 2020). In the USA, Next Generation Science Standards emphasise that students gain a better understanding of the nature of science and engineering within the scope of science and engineering practices, and the standards emphasise the importance of the integration of engineering design processes into science education at the K-12 level (Next Generation Science Standards [NGSS], the Lead States, 2013). In Turkey, science, engineering, and entrepreneurship practices were included in the middle school science curriculum in 2018 (Ministry of National Education [MoNE], 2018). The science, engineering and entrepreneurship practices aim to develop students’ entrepreneurial, science and engineering skills.

Entrepreneurship Mindsets (EM) and Engineering Design-based Activities

Entrepreneurship is the process of starting a business, taking risks, or taking action to develop, regulate and manage a business in an evolving competitive global market. An entrepreneur is a pioneer, innovator, and a leader. Entrepreneurship is not only an eco-

conomic value, but also a social and cultural phenomenon, and entrepreneurial individuals are the initiators of an innovative process (Aytaç & İlhan, 2007). An entrepreneurial individual is responsible for making decisions in any field. In other words, an entrepreneur is an individual who analyses the situation, predicts opportunities and problems, and makes rational decisions about the future. As shown in “An Entrepreneur’s Guide to the Big Issues” in **Figure 1**, entrepreneurial individuals follow the stages of “defining goals, developing the right strategies, and implementing the strategies”.

Entrepreneurial individuals move to the next stage of the entrepreneurial process if they are sure that their business can tolerate risk, that they have fulfilled their personal aspirations in the defining-targets step (**Figure 1**), and that they have determined their business sustainability and size. In the second step, the question “Do I have the right strategy?” helps to clarify definitions and helps to evaluate profitability and the potential for growth, durability, and the route to growth. If the answer is positive, the entrepreneur moves to the last stage: “Can I execute the strategy?” At this stage, to seek the answer to this question, the entrepreneur evaluates resources, organisational infrastructure, and the founder’s role.

Universities are effective in developing entrepreneurial characteristics. Entrepreneurship education enables students to develop entrepreneurship capabilities, understanding, attitudes, and motivation (Handayati et al., 2020). Students can be directed to new initiatives through their courses (Rasmussen & Sørheim, 2006). Entrepreneurship education is included in undergraduate programmes, especially in engineering, economics, and business departments. However, apart from these departments, the importance of interdisciplinary entrepreneurship education is emphasised to develop students’ entrepreneurial mindset (EM) (Jamira et al., 2021; Stenard, 2021). It is necessary to draw attention to the importance of entrepreneurship, which is thought to be related to commercial affairs in modern life, especially for teachers who are social engineers. However, the entrepreneurial skills of pre-service teachers are significantly lower than those of students of medicine, economics and administrative sciences, and engineering. One of the fields where entrepreneurship can be supported is science education (Bolaji, 2012). However, the science teachers’ level of knowledge about the concept of entrepreneurship and their tendency to develop their students’ entrepreneurship skills are limited (Deveci, 2016, 2018). Considering the science, engineering, and entrepreneurship practices in the science curriculum in Turkey, both science teachers and pre-service science teachers must have entrepreneurial skills (Aslan, 2021). The Kern Entrepreneurial Engineering Network (KEEN), which was created in 2005 to support the development of entrepreneurship skills of engineering students, sees entrepreneurship as a fundamental element of engineering education. KEEN states that in engineering education, students should develop as individuals who recognise opportunities, evaluate markets and learn from their mistakes (KEEN, 2021). Students’ EM are seen as an important component for the development of these skills (Liguori et al., 2018). The EM is a set of attitudes and skills that facilitates an engineer’s ability to innovate and create in a way that adds value to society (Riley et al., 2021). EM is framed by curiosity, connections, creating value, communication, collaboration, and character (Hylton et al., 2020).

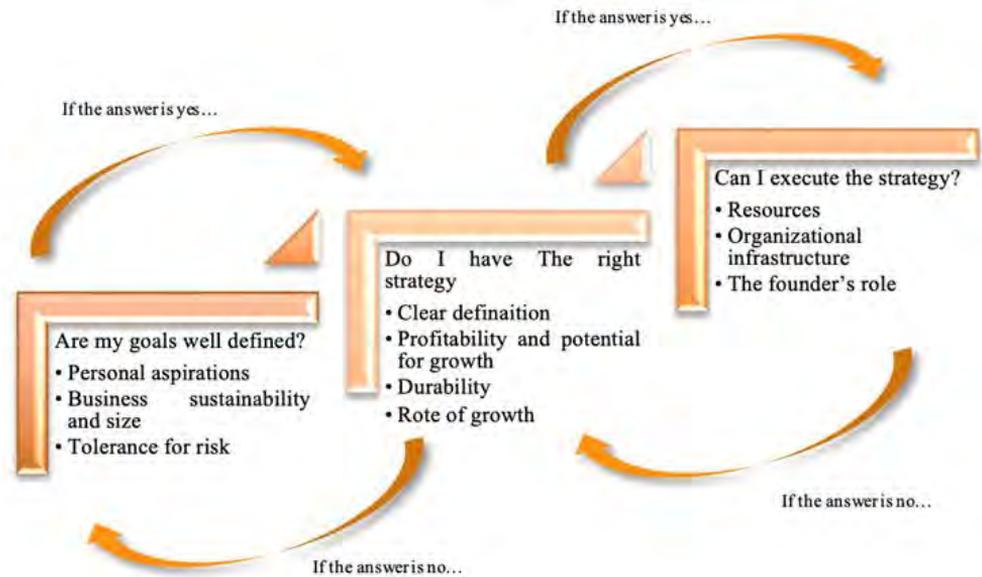


Figure 1. An Entrepreneur's Guide to Big Issues (Bhide 1996).

In science education, prompts to improve students' entrepreneurship mindsets are used during the presentation of the product developed for real-world problems in engineering design-based activities. In this research, the need for clean water and the evaluation of wastewater are discussed as real-life problems. The engineering discipline provides an important context for the development of entrepreneurial mindsets. However, individuals with entrepreneurial mindsets are needed to predict possible problems that may arise and to generate innovative solutions to these problems within the scope of the engineering design process.

To this end, it is important to create environments that will enable pre-service teachers to explore engineering design-based activities in their education. In this study, the science teaching laboratory practices course was restructured since there were no specific courses on engineering education and entrepreneurship in the undergraduate science education curriculum. Within the scope of the course, pre-service science teachers designed a water treatment system (WTS) and a wastewater assessment system (WwAS) by following the steps of the engineering design process, so that the entrepreneurship mindsets (curiosity, connections, creating value, communication, and collaboration, character) in solving the water pollution problem could be developed.

Method

Research Design and Participants

Table 1. Overview of the Research.

| Week | Content |
|------|--|
| 1 | What is Engineering? Engineering design process Science and engineering integration 21st-century skills: Entrepreneurship |
| 2 | Pilot activity: Design Gloves |
| 3 | Pilot activity: Light Sensor Curtain |
| 4 | Water Treatment System (WTS) |
| 5 | Wastewater Assessment System (WwAS) |

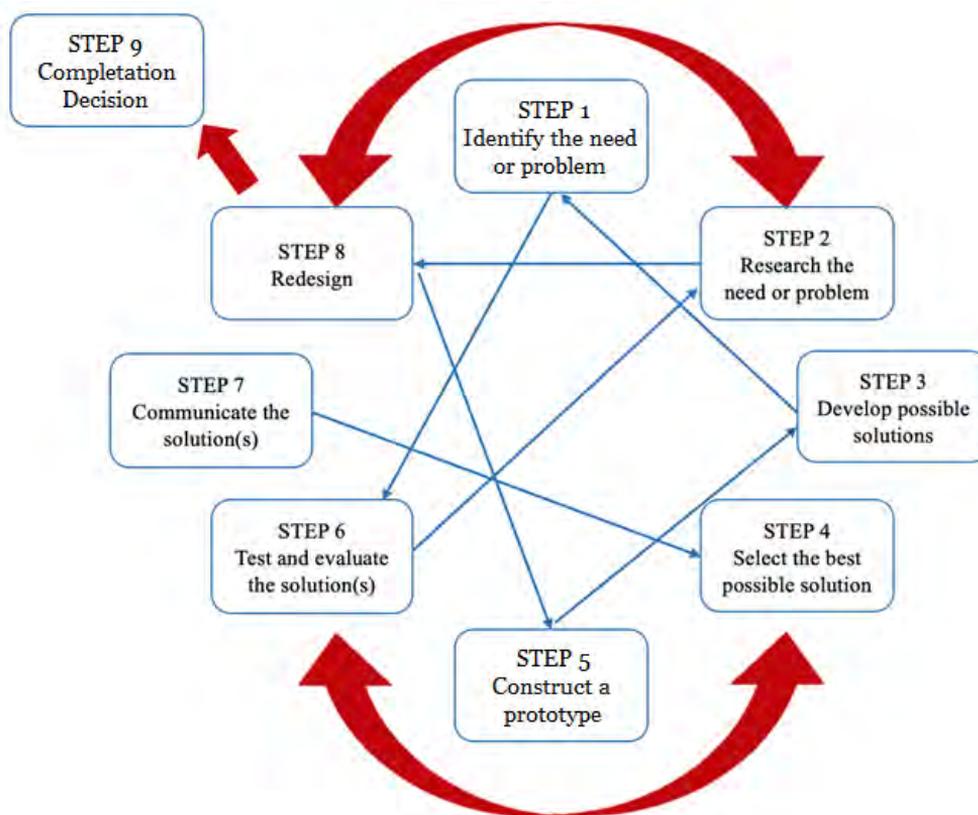


Figure 2. Engineering Design Process (Hynes et al., 2011, p.9).

Middle school student Leyla goes to her hometown for summer vacation. She hears that a relative has a problem with water pollution in her home. When she asks other relatives and neighbors, she realizes that water pollution is a common problem in their hometown. She prepares a project about what can be done to solve this problem

Figure 3. Real-World Problem Used in the “Water Treatment System” Activity.

This holistic single-case study was carried out over five weeks (20 hours) in the science teaching laboratory practice course, with 28 pre-service teachers (23 female, five male) in the third year of the four-year science teaching undergraduate programme.

Context of the Study

The science teaching programme of education faculties in Turkey is a four-year undergraduate programme. In the undergraduate science teacher education curriculum, there is a science teaching laboratory applications course in the third year. This course is the last laboratory course in the pre-service teachers’ programme. Before this course, students will have completed courses that cover the subject matter of physics, chemistry, and biology. The research was carried out within the scope of the laboratory course for five weeks (20 hours), as shown in **Table 1**.

The pre-service science teachers had not taken any courses in engineering and entrepreneurship education before the laboratory course. For this reason, as shown in **Table 1**, in the first week of the study, one of the researchers, who is also the course supervisor, gave information to the pre-service teachers about entrepreneurship and the engineering design process. The engineering design process steps (Hynes et al., 2011) indicated in **Figure 2** was explained to the pre-service teachers. In addition, the importance of engineering design-based activities and entrepreneurship skills for science education was discussed. The use of worksheets during the course was explained, particularly their focus on the engineering design process.

In the second week of the research, the “Design Gloves” activity, which is one of the pilot activities, was carried out to gain knowledge and experience about the engineering design process. In this activity, a grandmother with joint pain was asked to design a glove that would contribute to reducing her pain. While trying to solve this problem, pre-service teachers were asked to consider the concepts of heat, temperature, heat conduction, and insulation. In the third week of the research, the other pilot activity,

“Light Sensor Curtain”, was carried out. Pre-service teachers gained experience in designing curtains using motion and light sensors in this activity. In the pilot applications, pre-service teachers discussed the promotion and marketing of their designs. These activities aimed to contribute to the formation of EM.

In the fourth week of the research, the water treatment system activity was carried out. In this activity, pre-service teachers were asked to create solution proposals by taking into account the requirements of entrepreneurship skills through the engineering design process, based on the real- world problem (**Figure 3**).

The pre-service teachers were given time to create their solution proposals to the given problem. Then, they were asked to evaluate their possible solutions in terms of the criteria and limitations they had determined to choose the best possible solution. They made this evaluation by using a decision matrix in line with the criteria of “active carbon, sponge, electrolysis, boiling” solution proposals, and in line with the criteria of “cost, aesthetics, ease of production”. Then, the pre-service teachers were expected to prepare, test, and evaluate a prototype in line with their decision matrices. In the first prototype, they were asked to explain the decision to complete their project if there were no problems, and if a problem was detected, they were to return to the design process and re-evaluate their solution proposals to create the most accurate water treatment system. The prototype samples prepared by the pre-service teachers in the WTS activity are presented in **Figure 4**.

In the fifth week of the research, a wastewater treatment system was designed to proactivity water waste and draw attention to the global problem of water scarcity (**Figure 5**). In this activity, the pre-service teachers were requested to evaluate wastewater, especially in domestic use, by taking into account biological and chemical pollution.

The pre-service teachers were asked to plan an advertising slogan, advertising strategy, and sales strategy at the stage of presenting their products. They prepared these presentations in the form of public service announcements (PSA). The benefits to the target audience, the cost of the design, and its superior aspects were included in the PSA videos. The activities were concluded with students watching their PSAs and giving feedback on the redesign process.

Data Collection Tools

Research data were collected using the pre-service science teachers’ engineering design challenge worksheets and PSA.

Engineering Design Challenge Worksheets

Worksheets prepared with the engineering design process steps in mind (Hynes et al., 2011) were used in the research. Firstly, the pre-service teachers were provided with a scenario containing a problem typical of daily life. They were asked to identify the problem based on the presented scenario, to summarise the information obtained by

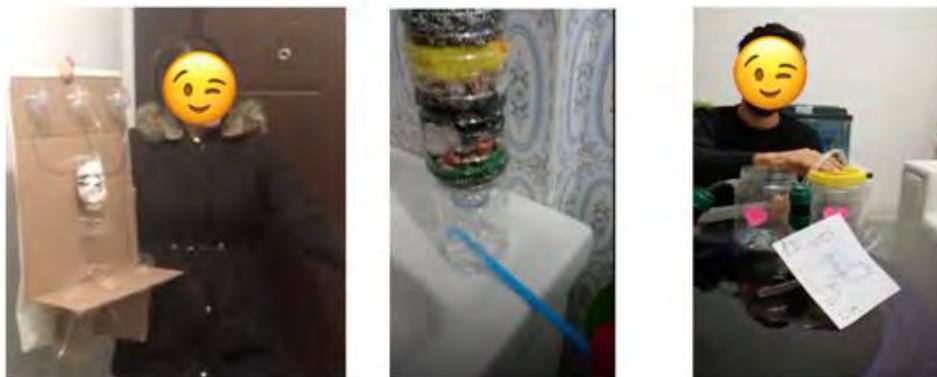


Figure 5. Examples of Student Products.

Public Service Announcement (PSA)

PSAs designed by the pre-service teachers using media design processes constitute the other data collection tool of the research. Media design processes enable students to learn by designing media products with technological tools (Liu, 2003). PSAs are an example of the integration of media design processes into education and are used to make students aware of social and environmental issues (Karahan et al., 2015; Lester et al., 2006). PSAs developed for science subjects enable students to learn science subjects (Newstetter, 2000) and develop life skills such as creative thinking, reflective thinking, and decision making (Hacıoglu et al., 2020). In this research, the pre-service science teachers developed 40 PSAs (20 groups, two each) related to the promotion, sales, and marketing of the products that emerged in the WTS and WwAS process. Each PSA was designed to last approximately 120-240 seconds.

Data Analysis

Extended KEEN Student Outcomes (eKSOs) rubric was used in the analysis of the data obtained from the worksheets and PSAs revealed by the pre-service teachers in the WTS and WwAS activities. The eKSOs were developed by Hylton et al. (2020) to evaluate the EM. The KEEN framework defines the EM in the context of engineering as the combination of curiosity, connections, and creating value, coupled with engineering thought and action, expressed through collaboration and communication, and founded on character. The eKSOs rubric is structured by considering six sub-dimensions of EM (curiosity, connections, creating value, communication, collaboration, character), and 53 mindset outcomes.

Table 2. Findings Related to Curiosity.

| eKSOs | f | f |
|--|-------|--------|
| | (WTS) | (WwAS) |
| Develops a propensity to ask MORE questions | 17 | 9 |
| Be able to formulate SALIENT questions | 0 | 9 |
| Questions information that is given without sufficient justification | 6 | 17 |
| Collects feedback and data from many customers and customer segments | 4 | 7 |
| Recognizes and explores knowledge gaps | 24 | 22 |
| Critically observes surroundings to recognize the opportunity | 22 | 25 |
| Views problems with an open mindset and explore opportunities with passion | 16 | 23 |
| Be able to self-reflect and evaluate preconceived ideas, thoughts, and accepted solutions | 7 | 16 |
| Explores multiple solution paths | 26 | 23 |
| Gathers data to support and refute ideas | 22 | 20 |
| Suspends initial judgment on new ideas | 8 | 11 |
| Takes ownership, and expresses interest in topic/expertise/project. Observes trends about the changing world with a future-focused orientation/perspective | 1 | 7 |

The worksheets and PSAs of the pre-service teachers were scored separately by two researchers using eKSOs. By evaluating the consensus and differences of opinion among the researchers (Miles and Huberman, 1994), the interrater reliability between the raters was calculated as 80%.

Findings

Curiosity

As seen in **Table 2**, the most frequently observed eKSOs related to the curiosity of the pre-service science teachers in engineering design-based activities, and, in the WTS activity, the most frequently observed eKSO was “explores multiple solution paths ($f = 26$)”. In the WTS activity, no outcome was determined on whether the participants were “able to formulate SALIENT questions”. In the WwAS activity, the eKSO “critically observes surroundings to recognise opportunity ($f = 25$)” was observed the most. “Collects feedback and data from many customers ($f = 7$)” and “takes ownership of, and expresses interest in the topic/expertise/project. Observes trends about the changing world with a future-focused orientation/perspective ($f = 7$)” was observed the least.

As seen in **Table 2**, students formed more entrepreneurial mindsets related to curiosity in the second WwAS activity. An increase was observed in entrepreneurial mindsets regarding “be able to formulate SALIENT questions” and “question information that is given without sufficient justification”, especially with engineering design-based activities. While pre-service teachers developed a propensity to ask more questions in the first activity, WTS, there was a decrease in this propensity in the second activity.

Table 3. Findings Related to Connections.

| eKSOs | f (WTS) | f (WwAS) |
|---|------------|-------------|
| Understands the ramifications (technical and non-technical) of design decisions | 13 | 15 |
| Identifies and evaluate sources of information | 22 | 18 |
| Connects life experiences with class content | 2 | 4 |
| Connects content from multiple courses to solve a problem | 1 | 9 |
| Integrates/synthesizes different kinds of knowledge | 4 | 12 |
| Considers a problem from multiple viewpoints | 24 | 23 |
| Persuades why a discovery adds value from multiple perspectives (technological, societal, financial, environmental, etc.) | 14 | 21 |
| Articulates the idea to diverse audiences | 8 | 18 |
| Understands how elements of an ecosystem are connected | 17 | 21 |
| Identifies and works with individuals with complementary skill sets, expertise, and so on | 0 | 1 |
| Develops a professional network | 1 | 5 |

Connections

“Consider a problem from multiple viewpoints ($f = 24$)” was the most frequently observed eKSO related to connections in the engineering design-based WTS activity of pre-service science teachers. “Identifies and works with individuals with complementary mindsets, expertise, and so on ($f = 0$)” was never observed. The most frequently observed eKSO in WwAS activity was “considers a problem from multiple viewpoints ($f = 23$)”, and the least observed was “identifies and works with individuals with complementary skill sets, expertise, and so on ($f = 1$)”, which was not observed at all in the WTS activity.

As can be seen in **Table 3**, the frequency of the recurrence in entrepreneurial mindsets regarding connections increased in the WwAS activity. In particular, the entrepreneurial mindsets of “articulates the idea to diverse audiences”, “connects content from multiple courses to solve a problem”, and “connects content from multiple courses to solve a problem” increased with engineering design-based activities.

Creating Value

The most frequently observed eKSO related to creating value in both WTS and WwAS activities based on the engineering design of pre-service science teachers was “integrate nonmonetary and monetary factors into a triple bottom line assessment ($f_{WTS} = 24$, $f_{WwAS} = 26$)”. The least observed eKSO was “describes how a discovery could be scaled and/or sustained, using elements such as revenue streams, key partners, costs,

Table 4. Findings Related to Creating Value.

| eKSOs | f (WTS) | f (WwAS) |
|--|------------|-------------|
| Identifies the needs and motivations of various stakeholders | 13 | 23 |
| Expresses empathy in identifying problems and exploring solutions. | 18 | 18 |
| Creates solutions that meet customer needs | 11 | 20 |
| Defines market and market opportunities | 14 | 23 |
| Crafts a compelling value proposition tailored to specific stakeholders | 11 | 13 |
| Integrates nonmonetary and monetary factors into a triple bottom line assessment | 24 | 26 |
| Applies technical skills/knowledge to the development of a technology/ product | 13 | 18 |
| Modifies an idea/product based on feedback | 2 | 5 |
| Focuses on understanding the value proposition of a discovery | 7 | 16 |
| Describes how the discovery could be scaled and/or sustained, using elements such as revenue streams, key partners, costs, and key resources | 3 | 8 |
| Engages in actions with the understanding that they have the potential to lead to both gains and losses | 7 | 10 |

Table 5. Findings Related to Communication.

| Items | f (WTS) | f (WwAS) |
|--|------------|-------------|
| Presents technical information effectively (graphs, tables, equations) | 18 | 20 |
| Identifies and organize information in a format suited to the audience | 16 | 18 |
| Provides and accept constructive criticism, including self-evaluation | 6 | 13 |
| Produces effective written reports | 13 | 8 |
| Produces effective verbal presentations | 0 | 10 |
| Manages informal communications (meetings, networking, etc.) | 5 | 11 |

and key resources ($f = 3$)” in the WTS activity. The least observed eKSO in the WwAS activity was “modifies an idea/product based on feedback ($f = 5$)”.

As can be seen in **Table 4**, an increase in the frequency of the repetition of all eKSOs related to creating value was detected in the WwAS activity. In particular, the entrepreneurial mindsets of pre-service teachers regarding “identify the needs and motivations of various stakeholders” improved with engineering design-based activities.

Communication

The most frequently observed eKSO in the WTS activity in the communication dimension was “presents technical information effectively (graphs, tables, equations) ($f = 18$)”,

Table 6. Findings Related to Collaboration.

| Items | f (WTS) | f (WwAS) |
|---|------------|-------------|
| Recognize their strengths, skills, and weaknesses, as well as those of others | 12 | 21 |
| Be able to lead, delegate, and follow | 7 | 5 |
| Be aware of and able to work through interpersonal conflict | 0 | 2 |
| Be able to teach and learn from peers | 0 | 5 |
| Be able to network and see the value of others | 9 | 17 |

Table 7. Findings Related to Character.

| Items | f (WTS) | F (WwAS) |
|---|------------|-------------|
| Demonstrate an ability to set, evaluate, and achieve personal and professional goals | 17 | 13 |
| Meet commitments | 3 | 2 |
| Recognize and evaluate potential impacts while making informed ethical and professional decisions | 18 | 20 |
| Accept responsibility for their actions, and credit the actions of others | 6 | 4 |
| Develop an appreciation of hard work and recognize the benefits of the focused and fervent effort | 1 | 4 |
| Work toward the betterment of society | 22 | 21 |

and the least observed eKSO was “manages informal communications (meetings, networking, etc.) (f = 6)”. “Produces effective verbal presentations” was never observed. The most frequently observed eKSO in the WwAS activity was “presents technical information effectively (graphs, tables, equations) (f = 20)” and the least observed eKSO was “produces effective written reports (f = 8)”.

According to **Table 5**, an improvement in eKSOs was observed in the communication dimension of the entrepreneurial mindset, including “provides and accepts constructive criticism, including self-evaluation”, “produces effective verbal presentations”, and “manages informal communications (meetings, networking, etc.)”.

Collaboration

In the collaboration stage, the most frequently observed eKSO in both activities was “recognise their strengths, skills, and weaknesses, as well as those of others (fWwAS = 21, fWTS = 12)”, while the least observed eKSO in the WTS activity was “be able to network and see the value of others (f = 7)” and the least observed eKSO in the WwAS activity was “be aware of and be able to work through interpersonal conflict (f = 2)”. The eKSOs “be aware of and able to work through interpersonal conflict” and “be able to teach and learn from peers” were not observed in the WTS activity (**Table 6**).

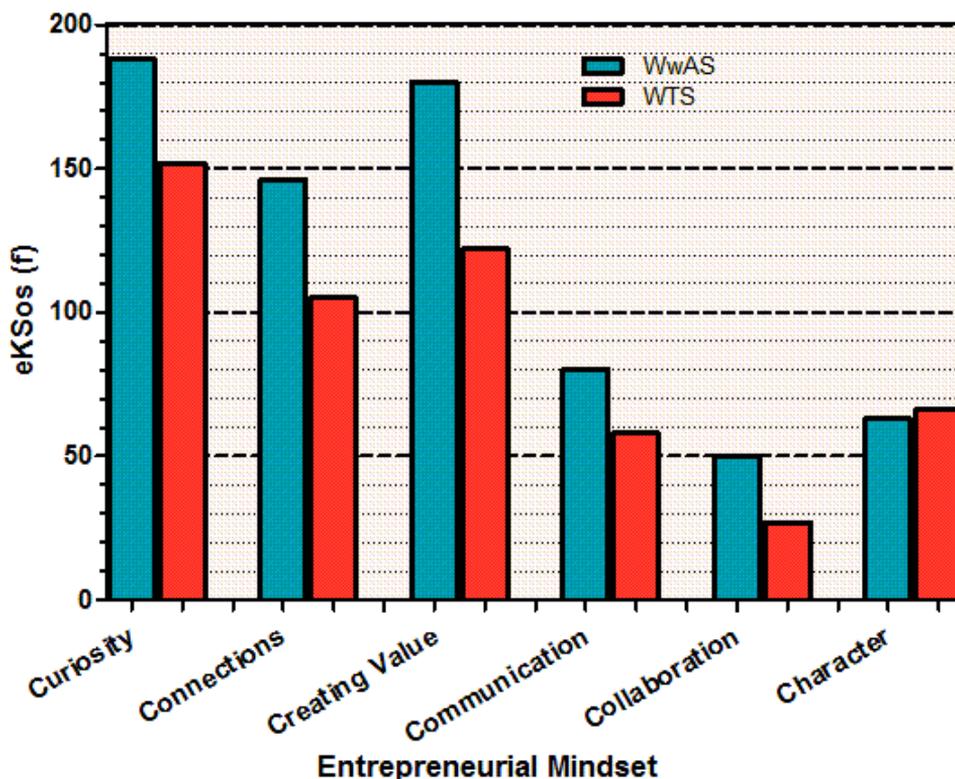


Figure 6. Overall Evaluation of Pre-service Science Teachers' Entrepreneurial Mindsets.

In the collaboration dimension of the entrepreneurial mindset, the incidence of the eKSOs “recognise their strengths, skills, and weaknesses, as well as those of others” and “be able to network and see the value of others” increased in the WwAS activity. “Be aware of and able to work through interpersonal conflict” and “be able to teach and learn from peers” were never observed in the WTS activity, but were detected in the WwAS activity.

Character

Character was also the most frequently observed eKSO partner in the “WwAS” and “WTS” activities. The most frequently observed behaviour was “work toward the betterment of society” (fWwAS = 21, fWTS = 22); the least observed was “develop an appreciation of hard work and recognise the benefits of focused and fervent effort (f =

1)” in the WTS activity and “meet commitments (f = 2)” in the WwAS activity (**Table 7**).

In this sub-dimension, frequencies of items such as “demonstrate an ability to set, evaluate, and achieve personal and professional goals”, “accept responsibility for their actions and credit the actions of others”, “work toward the betterment of society”, and “meet commitments” at the WTS activity was high. In the WwAS activity, the frequencies of the items “recognise and evaluate potential impacts while making informed ethical and professional decisions”, and “develop an appreciation of hard work and recognise the benefits of focused and fervent effort” were found to be high.

When the entrepreneurial mindsets of pre-service science teachers were evaluated overall within the scope of the “curiosity, connections, creating value, communication, collaboration and character” sub-dimensions, the eKSOs related to curiosity, connections, and creating value were observed the most. eKSOs related to communication, character, and collaboration were repeated less frequently compared to curiosity, creating value and connections (**Figure 6**).

As shown in **Figure 6**, the pre-service teachers’ entrepreneurial mindsets (except for the character sub-dimension) improved in WwAS effectiveness. In particular, the frequency of abandonment of eKSOs related to creating value increased. A lesser increase was observed in the communication and collaboration sub-dimensions compared to the other sub-dimensions. There was a decrease in the number of eKSOs for character.

Discussion and Conclusion

In this study, which examined the entrepreneurial mindsets of pre-service science teachers in engineering design-based thematic activities, the entrepreneurial mindset outcomes of the curiosity, creating value, and connections sub-dimensions were observed the most in the activities. Riley et al. (2021) stated that even the activities carried out in a single semester have a great impact on the development of university students’ entrepreneurial mindsets regarding curiosity, creating value, and connections sub-dimensions. Researchers recommend early intervention in the EM development process by providing students with unique, exploratory, and hands-on experiences.

Within the scope of other entrepreneurial mindsets, the outcomes related to collaboration were observed the least. Although the pre-service teachers were in the same class as their peers for three years, they found it difficult to collaborate at the beginning of this study and after the activities. Experience is important for pre-service teachers to cooperate and learn the importance of cooperation (Kropp et al., 2016). In a study in which collaborative project-based learning was applied, while task-related conflict contributed to cooperation, process and relationship conflicts harmed and prevented learning (Lee et al., 2015). The necessity of team harmony consisting of teamwork, interpersonal interactions, and mutual trust and cooperation among team members should also be taken into account (Kao, 2019).

The development of the pre-service teachers' mindsets regarding communication, character, and collaboration in the engineering design-based activities was limited. It is important to include activities that will enable the development of these mindsets before students enter tertiary education. In this respect, it is significant to include science, engineering and entrepreneurship applications in secondary school science courses in Turkey (MoNE, 2018). However, the limitations of pre-service teachers' EM may affect the development of students' EM in their classrooms in the future. In line with this result, instructors in the college of education should structure their lessons in a way that develops the mindsets of future science teachers.

A limitation of this study is that although pre-service teachers were informed about the engineering design process, no entrepreneurship training was given. According to Handayati et al. (2020) entrepreneurship education positively leads to students' entrepreneurship intention and an entrepreneurial mindset. The development of these mindsets can be supported by implementing curricular and extracurricular engineering design-based activities for pre-service teachers. Overall, our results provide evidence that pre-service science teachers need more training in entrepreneurship. Entrepreneurship education provides students with a deep understanding of entrepreneurship and encourages students to gain the experience needed to become entrepreneurs (Fayolle & Gailly, 2015).

In this research, engineering design-based activities were carried out under the theme of water pollution. The entrepreneurial mindsets of pre-service teachers showed a tendency to improve in the second activity, the WwAS activity. More time can be allocated to activities that will enable pre-service teachers to develop their entrepreneurial mindsets, and activities can be implemented according to different themes. In this way, pre-service teachers can be supported to gain experience in engineering design-based activities.

For the development of entrepreneurial mindsets, different pedagogical methods can be used, not only at the presentation stage of the design process but also at all stages. Activities that will support the entrepreneurial mindset of pre-service science teachers can be included in courses other than laboratory courses. The design of these activities can focus on communication, character, and collaboration, which are less of a focus in this research.

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Received: 27 February 2022

Revised: 29 March 2022

Accepted: 04 April 2022