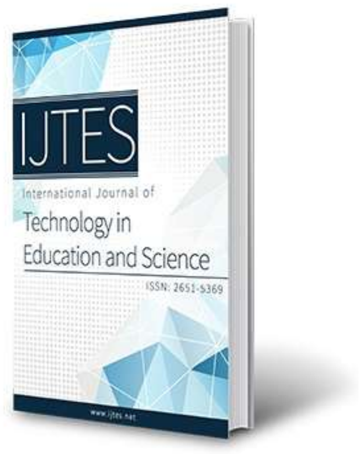

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Mehmet Enes Kahraman
Erciyes University, Turkiye

Fulya Öner Armağan
Erciyes University, Turkiye

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Opinions of Science Teacher Candidates on their Competence in Designing STEM Activities

Mehmet Enes Kahraman, Fulya Öner Armağan

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Abstract

This research aims to examine the competencies of pre-service science teachers in designing STEM (Science, Technology, Engineering, Mathematics) activities and the challenges they encounter in this process. The study was carried out using phenomenology, one of the qualitative research designs. A total of 23 second-year pre-service science teachers studying at a state university in the Central Anatolia Region, who had prior experience with STEM activities, were selected through purposive sampling. Data were collected through documents and analyzed using content analysis. The findings indicate that pre-service teachers perceive themselves as competent in STEM applications but experience difficulties during the implementation phase. Participants reported challenges in the design phase, particularly in areas such as interdisciplinary integration, planning, lack of creativity, lack of experience, and time constraints. To overcome these challenges, they suggested engaging in more practice, seeking guidance, and conducting research. Additionally, participants stated that group work and manual skills facilitated the design phase. While they found themselves inadequate in integrating science and engineering into STEM applications, they considered themselves competent in integrating mathematics and technology. Participants will be able to do more to increase the effectiveness of STEM applications. They want training and assignments for STEM applications. This study provides recommendations for improving the self-efficacy of pre-service teachers in STEM applications and optimizing implementation processes.

Introduction

STEM (Science, Technology, Engineering, and Mathematics) combines four disciplines: science, technology, engineering, and mathematics, and is based on the integration of these disciplines (Belek, 2018; Chiu et al., 2015; Dugger, 2010; Kelley and Knowles, 2016; Meng et al., 2014). STEM aims to provide a qualified education that effectively and memorably facilitates learning, integrates disciplines, and presents real-life problems through the STEM approach (Bybee, 2013). The goals of STEM education include ensuring that individuals improve their knowledge acquisition, providing individuals with technological literacy, achieving success in the disciplines of science and mathematics, and increasing interest in engineering understanding and engineering careers (Gülhan and Şahin, 2016). STEM education can contribute to the development of individuals' 21st-century skills

(Stohlmann, Roehrig, and Moore, 2014). The benefits of STEM education include ensuring the integration of related disciplines, applying knowledge in real life, developing critical thinking and problem-solving skills, boosting self-confidence, promoting active communication and teamwork, fostering interest in technical disciplines, and preparing individuals for technological innovations (Morze Smyrnova-Trybulska and Gladun, 2018). The need for individuals to acquire these skills has led to innovations in the education systems of countries, and various teaching methods and approaches have begun to be used. In this context, the idea of equipping students in schools with the ability to solve real-life problems through STEM has come to the forefront. STEM education has also been among these new approaches, encompassing many fields and skills (Başaran and İlter, 2023). Considering the competitive environment in the fields of economy and technology today, it is very important to train individuals with proficiency in STEM (Eroğlu and Bektaş, 2016). The concept of self-efficacy is also very important in the learning process. According to Bandura's definition, the concept of self-efficacy is defined as an individual's subjective perception of successfully performing a task required to demonstrate competence (Bandura, 1977). One of the important factors affecting a teacher's decisions in the classroom is the teacher's confidence in the adequacy of their instructional activities, in other words, their self-efficacy belief (Tschannen et al., 2001). It has been observed that STEM practices are effective in the development of self-efficacy among science teacher candidates (Kendaloğlu, 2021). The importance of teachers in raising qualified individuals is significant. In this context, it is important for teacher candidates to start their professional lives fully prepared (Kendaloğlu, 2021). In order for STEM education to be effectively implemented, teacher training in this area should be prioritized (Kelley and Knowles, 2016). The literature studies related to STEM self-efficacy are as follows:

In Belek's (2018) study, it was determined that the STEM approach does not have a significant effect on the self-efficacy beliefs of Science Teacher Candidates, but it positively contributes to the development of their thoughts on teaching Science. In Şimşek's (2019) study, it was found that Science Teachers had high self-efficacy beliefs regarding science teaching and integrating mathematics into science teaching. In some studies, it has been determined that science teacher candidates' self-efficacy towards STEM practices is at a moderate level (Verdi, 2024) or a good level (Er and Başeğmez, 2020). In the studies of Arslan (2018) and Abacı (2020), it was found that STEM applications positively affected the self-efficacy of science teacher candidates towards science teaching. In Kendaloğlu (2021)'s study, it was determined that science teacher candidates' self-efficacy towards STEM improved after receiving STEM education. It has been determined that STEM applications increase the self-efficacy of students pursuing a master's degree in science education towards STEM applications (Özkaya et al., 2022) and enhance the self-efficacy of science teacher candidates towards science teaching (Timur and Belek, 2021). In the relevant literature, various studies addressing STEM self-efficacy in science education have been conducted (Abacı, 2020; Arslan, 2018; Belek, 2018; Kendaloğlu, 2021; Şimşek, 2019; Timur and Belek, 2021). However, there are a limited number of studies examining the competencies of Science Teacher Candidates regarding STEM applications (Er, Başeğmez, 2020; Özkaya et al., 2022; Verdi, 2024). This study aims to address the self-efficacy of science teacher candidates in designing STEM activities and the challenges they encounter in this process, contributing to the resolution of deficiencies in this area and the development of recommendations. In this context, the research question of the study is "What are the views of science teacher candidates regarding their competencies in developing STEM activities?"

Method

Study Design

This study was conducted using the phenomenology design, one of the qualitative research designs, to examine the experiences of science teacher candidates in the process of designing STEM activities. Phenomenology is a design that investigates individuals' experiences of a specific phenomenon and the meanings they attribute to these experiences (Creswell, 2007). In this context, the competencies of teacher candidates towards the STEM approach, the challenges they face, and their experiences have been examined in detail.

Study Group

In this study, a non-probability sampling approach known as purposive sampling has been used. Purposeful sampling, which facilitates comprehensive research by identifying information-rich cases in accordance with the specific objectives of the study, is preferred when the aim is to examine one or more unique cases that meet specific criteria or possess different characteristics (Başaran, 2017). In this study, the criterion sampling type of purposive sampling (Saylan Kırmızıgül and Öner Armağan, 2023) was preferred. In a criterion sampling group, the study group is formed from individuals, objects, or situations that possess the characteristics determined in relation to the problem (Büyüköztürk et al., 2021). Accordingly, the participants of the study were selected from second-year teacher candidates studying at a state university located in the Central Anatolia Region during the 2024-2025 academic year. It was selected from teacher candidates who participated in STEM education as a criterion. The opinions of the twenty-three teacher candidates were coded as K-1, K-2, K-3 … K-23.

Data Collection Tool

In the research, a document was used as a data collection tool. A document is a written tool used to gather information on a specific topic. Documents are commonly used to deeply understand the experiences and thoughts of participants (Yıldırım and Şimşek, 2021). In this study, a questionnaire consisting of open-ended questions was used to understand the experiences, competencies, and challenges faced by science teacher candidates regarding STEM activities. The questions were developed by the researchers through a literature review (Öner Armağan and Atalay, 2023; Verdi, 2024).

Data Collection Process

The data was collected during the fall semester of the 2024-2025 academic year and the data collection took about one class hour.

Validity and Reliability

To ensure the internal validity of the study, expert opinions were sought before administering the questionnaire prepared by the researchers for use in the study. The opinions of a science educator were obtained regarding the prepared questionnaire. In line with the expert's opinion, the researchers reviewed the interview form regarding the clarity and appropriateness of the questions and made the necessary corrections (see Appendix for the interview questions). Before the interview, explanations were provided to the participants, and an attempt was made to create a natural conversational atmosphere between the participants and one of the researchers. The participants' responses to the questions were presented as direct quotes in the findings section.

To ensure external validity, the participants of the study were selected in accordance with the purpose of the study. The researchers reached a consensus on the appropriateness of the research data.

STEM Activity Implementation Process: Design of STEM Material for the Digestive System

This study aims to have pre-service science teachers develop an educational material for the digestive system using the engineering design process with the STEM approach. The engineering design process is a cyclical, creative and dynamic approach that involves developing a tool to solve engineering problems or creating a process for a specific goal (NAE and NRC, 2009). The implementation process in the study was structured in line with the engineering design process defined by Hynes (2011) and the basic principles of STEM education.

Problem Identification

Real-life problems are one of the basic elements of STEM education (Breiner et al., 2012; Capraro and Slough, 2013; NAE and NRC, 2009). In this context, a STEM activity was designed for pre-service teachers to solve a problem encountered in science teaching.

Needs Identification

It is known that STEM education improves students' scientific process skills (Herdem and Ünal, 2018). For this reason, in order for STEM applications to be implemented effectively, students need to have a strong knowledge base about scientific concepts. At this stage, teacher candidates conducted research on digestive systems using academic resources. Teacher candidates sought answers to the following questions:

How should the digestive system be taught?

What types of materials are effective for students to understand the subject better?

Developing Solution Proposals and Determining the Best Solution

STEM activities contribute to students' development of critical thinking skills (Mater et al., 2020) At this stage, teacher candidates presented solution suggestions in line with the determined problem.

1-Creating a visual material using organ models

2-Producing a model showing organs with 3D printing technology

3-Designing an interactive STEM material with an integrated electrical circuit

As a result of the evaluation, teacher candidates decided which solution would be the most effective. In this direction, it was decided to draw the digestive system organs on cardboard and create an electrical circuit connected to the organs and illuminate the digestive organs.

Making the Prototype

This solution was designed to be compatible with the components of the STEM approach (Nughara et al., 2014):

Science: The basic functioning of the digestive system was addressed.

Technology: An interactive material was developed using an electrical circuit and LED lights.

Engineering: The material was structured in accordance with the engineering design process.

Mathematics: The organs were drawn proportionally to make the material realistic while drawing.

Pre-service teachers followed the engineering design process suggested by Hynes (2011) when designing the STEM activity. This process includes the stages of problem definition, research, prototyping, testing and improvement.

• Drawing digestive system organs on cardboard
• Creating an electrical circuit connected to the organs
• Testing the circuit and correcting incorrect connections
• Visually enriching the material

Testing and Evaluation

It is stated that in the engineering design process of the STEM application process, students create projects to solve real-world problems and in this process, they conduct research, produce multiple ideas for solutions, create prototypes, test them and evaluate them, and redesign and reevaluate them until they reach their goals (Hynes, 2011). In this context, it can be said that the testing process has a significant effect on learning in this cycle. At this stage, teacher candidates tested the material they designed and made the following evaluations:

• It was observed whether the electrical circuit worked correctly.
• It was confirmed that the lighting mechanism of the organs worked correctly.
• The educational value of the material was evaluated by receiving user feedback.

In line with the findings obtained during the testing phase, teacher candidates concluded that the material needed to be improved and made the necessary arrangements and prepared the final version.

Results and Sharing

As a result of this study, teacher candidates:

• Demonstrated the use of the material by presenting their work in class,
• Discussed how the material could be improved by receiving user feedback,
• Planned to make similar STEM-based designs for different subjects in the future.

Redesign

Teacher candidates made the following changes:

Resistance calculations in circuit connections were corrected.

The model was brought closer to reality.

As a result of these changes, it was observed that the material became more effective.

Products Resulting from the Application

The products whose visuals are given below are examples of materials designed by teacher candidates.

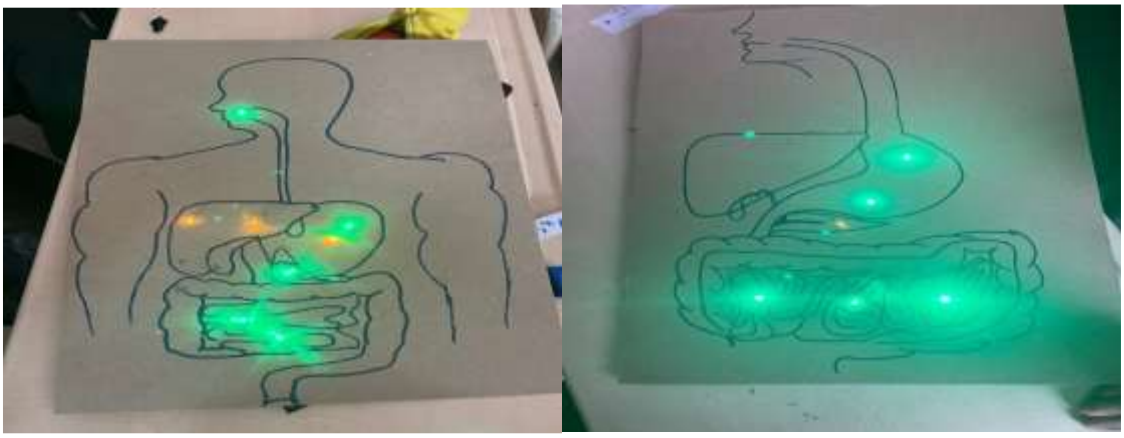

Figure 1. STEM Designs

Data Analysis

In this study, content analysis was used to analyze the qualitative data obtained from the questionnaire. In the study, direct quotations were provided to support the codes created in the content analysis. Content analysis is defined as a technique for systematically summarizing, categorizing, and coding the content of a text related to a subject using words or phrases that reflect the content, according to predetermined rules set by researchers (Büyüköztürk et al., 2021). When conducting content analysis, qualitative data that show similarities in the dataset examined by the researcher are organized under certain themes and categories (Özdemir, 2010). In this study, it is aimed for teacher candidates to answer the questions sincerely and for these answers to be analyzed in depth. For this purpose, the data were analyzed through content analysis based on the responses given by teacher candidates to six open-ended questions and the probes related to some of the questions. The codes obtained as a result of this analysis are presented in tables in the findings section.

Results

Codes were created according to the answers given by the prospective science teachers to the open-ended questions and are indicated in the relevant tables. The findings are given below in tables, respectively.

Question 1: Do you consider yourself sufficient in STEM applications? Why?

Probe: Could you explain in which areas/steps you are sufficient or insufficient?

Table 1. Findings regarding the Status of Being Sufficient in STEM Applications

Code	Participants
Sufficient	K-1, K-3, K-4, K-11, K-12, K-15, K-16, K-18, K-19, K-23
Partially sufficient	K-6, K-13, K-14, K-21
Insufficient	K-5, K-7, K-9, K-10, K-20, K-22

Most prospective teachers consider themselves competent for STEM practices.

Table 2. Findings regarding the Reasons for Inadequacy in STEM Applications

Codes	Participants	Statements
Implementation phase	K-5, K-8, K-11, K-12, K-20,	K-8: …I have difficulty doing applications.
Engineering	K-1, K-9, K-21	K-9: I find myself inadequate in engineering because it seems complicated.
Drawing phase	K-6, K-14	K-6: I feel inadequate in drawing.
Technology	K-17, K-22	K-17: I feel inadequate in using technology…
Lack of creativity	K-5	K-5: …because I do not find my creativity skills sufficient
Science	K-7	K-7: I do not find myself sufficient in the field of science
Mathematics	K-21	K-21: …I have trouble with the math step
Discipline integration	K-16	K-16: I may have difficulty using design with different disciplines.

Prospective teachers stated that they had deficiencies in knowledge in the application phase, such as setting up a circuit, the drawing phase, application, lack of creativity, and science, technology, mathematics, engineering and disciplinary integration. They based their deficiencies mainly on the application process, engineering, the drawing phase and the use of technology.

Table 3. Findings regarding the Reasons for Being Competent in STEM Applications

Code	Participants	Statements
Implementation phase	K-4	K-4: I think I am sufficient in the application stage.
Knowledge competence	K-11, K-12	K-11: …I can say that I know almost everything in theory.

Prospective teachers think that they are competent due to their science knowledge, application stage and knowledge accumulation.

Question 2: Do you have difficulty in designing STEM applications? Why?

Probe: At which stage do you have the most difficulty? Why? What are your solution suggestions for this?

Table 4. Findings regarding the Reasons for Difficulties in the Design Phase

Code	Participants	Statements
Interdisciplinary integration	K-17, K-18, K-20, K-21, K-23	K-20: At the engineering and mathematics stage because my basic knowledge in these areas is not sufficient…
Planning phase	K-19, K-20, K-22, K-23	K-19: I have difficulty in the planning stage
Lack of creativity	K-5, K-6, K-11, K-16	K-11: … I may have difficulty in making something that has never been made from scratch.
Lack of experience	K-5, K-8 K-17, K-21	K-8: … I was a little scared and had a hard time because I had never done such an activity on my own before…
Time problem	K-6, K-19, K-23	K-6: … I think more creative activities will emerge when time is more.
Material supply	K-7, K-23	K-7: It may be a little expensive to do financially
Attention problem	K-9	K-9: … because it requires a lot of attention.
Integration into education system	K-18	K-18: The education system applied is not suitable for STEM education and it is very difficult to find a relevant subject and integrate STEM into that subject.

Among the difficulties experienced by prospective teachers in the design phase, factors such as project planning, lack of creativity, lack of experience, time constraints, material supply and interdisciplinary integration came to the fore.

Table 5. Findings regarding the Reasons for Not Having Difficulty in the Design Phase

Codes	Participants	Statements
Group working	K-2, K-10	K-10: …we did the activity we did very successfully as a group…
Manual dexterity	K-3	K-3: I am prone to this kind of work.

Some prospective teachers stated that they did not have any difficulties in the design phase, especially due to the benefits of group work and manual skills.

Table 6.Findings regarding Suggestions to Avoid Difficulties in the Design Phase

Codes	Participants	Statements
Practicing	K-3, K-5, K-6, K-15, K-17	K-3: …I think I can improve myself by working more for this. K-5: …I think I will not have any difficulty if I do these practices continuously
Guiding	K-4, K-5	K-4: … how to do the activity should be explained better. K-5: … the guide needs to show.
Researching	K-12, K-23	K-12: … research should be done before the activity…
Taking an engineering course	K-18	K-18: … to eliminate this, a simple level lesson can be given on the engineering part of STEM.
Group working	K-23	K-23: … Teamwork.

In order to overcome these difficulties, teacher candidates suggested more practice, taking guidance support, conducting research, receiving engineering education, and increasing group work

Question 3: Do you consider yourself competent in integrating science into your STEM practices? Explain with reasons.

Probe-a. Do you consider yourself competent in integrating Mathematics into your STEM practices?
Probe-b. Do you consider yourself competent in integrating Technology into your STEM practices?
Probe-c. Do you consider yourself competent in integrating Engineering into your STEM practices?

Table 7. Findings regarding Competencies in Integrating Science into STEM Practices

Codes	Participants
Adequate	K-1, K-3, K-8, K-11, K-15, K-16, K-23
Inadequate	K-2, K-9, K-10, K-12, K-13, K-17, K-18, K-20, K-22
Partially adequate	K-4, K-7, K-14, K-19, K-21

The majority of teacher candidates feel inadequate in integrating science into STEM practices.

Table 8. Findings regarding the Reasons for Inadequate Integration of Science into STEM Practices

Code	Participants	Statements
Inexperience	K-9, K-10, K-20, K-22, K-23	K-9: … I am new to seeing the examples and I had not done many activities before…
Problem of integration into new program	K-12, K-18	K-12: It is a bit difficult to adapt to the new education model in science…
Lack of knowledge	K-4, K-17	K-4: … because science is a broad field and it is necessary to master physics, chemistry and biology courses separately. At this point, I think I may have difficulties while designing and I will feel incomplete.
Inability to establish interdisciplinary integration	K-19, K-23	K-19: … because it is difficult to combine different disciplines
Material selection	K-19	K-19: … I am in doubt about which tools and equipment I should use for the application.

Prospective teachers who felt inadequate attributed this situation to reasons such as inexperience, inability to establish interdisciplinary integration, and material selection.

Table 9. Findings regarding the Reasons for Integrating Science into STEM Practices

Codes	Participants	Statements
Knowledge level competence	K-3, K-8, K-13, K-23	K-3: … because I see myself as sufficient in terms of knowledge and I think I can process my knowledge into the material well.
Establishing interdisciplinary integration	K-5	K-5: … it will be easy to relate these to technology at this point

Prospective teachers who think they are competent see themselves as competent in integrating STEM applications into science lessons. These candidates stated that they easily managed this process thanks to their knowledge level competence and interdisciplinary integration.

Table 10: Findings regarding the Competence in Integrating Mathematics into STEM Applications

Code	Participants
Adequate	K-1, K-6, K-9, K-10, K-11, K-13, K-14, K-15, K-17, K-18, K-20, K-22
Partially adequate	K-4, K-7, K-16, K-23
Inadequate	K-2, K-5, K-12, K-19, K-21

Most of the prospective teachers mentioned that they found themselves sufficient in integrating mathematics into STEM practices.

Table 11. Findings regarding the Inadequacy of Integrating Mathematics into STEM Practices

Codes	Participants	Statements
Inability to integrate across disciplines	K-2, K-5,	K-2: I have a hard time when math and science come together, especially in physics and engineering.
Lack of knowledge	K-12, K-19	K-12: I may be inadequate in math
Inexperience	K-5	K-5: I feel inadequate in this subject because we haven't done any work using math

Prospective teachers who are inadequate in integrating mathematics into their practices focused on inexperience, inability to establish interdisciplinary integration, and lack of knowledge.

Table 12: Findings regarding the Reasons for Integrating Mathematics into STEM Practices

Codes	Participants	Statements
Knowledge level competence	K-9, K-10, K-11	K-11: …I am confident in mathematics.

Prospective teachers who are competent in integrating mathematics into their practices stated that their knowledge level is sufficient.

Table 13: Findings regarding the Category of Competence in Integrating Technology into STEM Practices

Code	Participants
Adequate	K-1, K-3, K-4, K-5, K-6, K-11, K-12, K-13, K-18, K-19, K-20, K-21
Partially adequate	K-2, K-8, K-9, K-14, K-15, K-16, K-23
Inadequate	K-7, K-10, K-17, K-22

Many of the prospective teachers stated that they felt competent in integrating technology into STEM practices.

Table 14. Findings regarding the Reasons for Competence in Integrating Technology into STEM Practices

Codes	Participants	Statements
Experience	K-1, K-3, K-5, K-11, K-18, K-19, K-20	K-3: I feel competent in the field of technology
Following technological developments	K-6	K-6: I think that as long as I follow technological innovations, I will be competent in integrating technology.
Interest	K-11	K-11: Because I am interested in technology, so I am quite knowledgeable.
Science-technology integration	K-12	K-12: Technology is very much related to science, so I use technology.

Prospective teachers who are competent in integrating technology into their practices mentioned that they are interested in and experienced in the field of technology, follow technological developments, and can establish science-technology integration.

Table 15. Findings regarding the Inadequacy of Integrating Technology into STEM Applications

Codes	Participants	Statements
Not following technological developments	K-7, K-13	K-7: …because technology is constantly evolving. I don't find myself very competent in following this development.
Lack of knowledge	K-8	K-8: So I don't have much knowledge...
Inexperience	K-10	K-10: I'm not very experienced in this regard.

Prospective teachers who felt inadequate or partially adequate stated that they felt inadequate due to lack of knowledge, inexperience and not following technological developments.

Table 16. Findings regarding the Category of Competence in Integrating Engineering into STEM Applications

Code	Participants
Adequate	K-5, K-12, K-15, K-17
Partially adequate	K-3, K-19
Inadequate	K-1, K-2, K-6, K-7, K-8, K-9, K-10, K-11, K-13, K-14, K-16, K-18, K-20, K-21, K-22, K-23

While prospective teachers mentioned that they were inadequate in integrating engineering into STEM practices, a few prospective teachers mentioned that they were sufficient.

Table 17. Findings regarding the Inadequacy of Integrating Engineering into STEM Practices

Codes	Participants	Statements
Inexperience	K-10, K-23	K-10: Because I have no experience in engineering.
Disinterest	K-2, K-10, K-21	K-2: Because I do not like things related to engineering…
Lack of knowledge	K-6, K-18	K-18: Lack of knowledge in the field of engineering makes it difficult for me to integrate
A broad field	K-19	K-19: Since engineering is a very broad concept, I feel partially sufficient.
No engineering education	K-21	K-21: I am not sufficient because I have not received any training on this before…

Prospective teachers who felt inadequate often attributed this to lack of experience and disinterest.

Table 18. Findings regarding the Reasons for the Competence of Integrating Engineering into STEM Applications

Codes	Participants	Statements
Interest	K-5, K-12, K-15, K-17	K-12: I do research because of my curiosity about engineering subjects.

One of the prospective teachers who felt competent attributed this to being interested in the subject.

Question 4: What can be done to increase the effectiveness of STEM applications?

Table 19. Findings for the Category of Development of STEM Applications

Codes	Participants	Statements
Teacher training should be provided	K-2, K-3, K-6, K-10, K-13, K-16, K-17, K-23	K-13: Training can be organized for teachers on STEM-based digital tools, engineering applications, and mathematics integration.
Increasing widespread impact	K-1, K-3, K-11, K-20	K-11: Education should be provided on this subject at universities and graduated teachers should be informed through conferences and seminars……
Elective courses should be opened	K-3, K-10	K-3: I think that adding some elective courses will increase the knowledge and skills of teacher candidates.
Theoretical information should be reduced	K-5	K-5: Theoretical information in the courses can be reduced from the curriculum so that there can be more time for practice.
STEM-based homework should be given	K-19	K-19: Students should be given homework based on real-world problems

Most prospective teachers stated that training programs for teachers should be developed for STEM to be implemented effectively. Some candidates stated that adding STEM-themed elective courses would increase the knowledge and skills of prospective teachers. It was suggested that STEM applications should be expanded, projects should be given based on real-world problems, and theoretical knowledge should be reduced and more practice should be done.

Discussion and Conclusion

This study aimed to examine the views of science teacher candidates on their competencies in designing STEM activities. According to the findings of the study, it was concluded that the majority of teacher candidates felt cognitively sufficient in STEM practices. It has been stated that this is supported by their knowledge base, science skills, and experiences related to applications. However, some teacher candidates considered themselves somewhat adequate in specific areas such as discipline integration and engineering, while a small number expressed feelings of inadequacy, particularly in areas like the application process, drawing, and creativity. In the relevant literature, studies have been found indicating a positive level of STEM self-efficacy (Ateş and Gül, 2023; DeCoito and Myszkal, 2018; Değirmenci, 2020; Fenton and Esler-Petty, 2019; Kelley et al., 2020; Kendaloğlu, 2021). For example, in the study by Fenton and Esler-Petty (2019), it was stated that robotic STEM applications increased the STEM self-efficacy of teacher candidates. In the study by Kelley et al. (2020), it is stated that science teachers' self-efficacy increased after professional training and practical courses, and that teachers benefited from the science and engineering design process while solving real-life problems. However. In Ergül's (2021) study, it is observed that the STEM competencies of teacher candidates are low. In the study by Er and Başeğmez (2020), it was determined that the teacher candidates' competencies regarding STEM practices were at a moderate level.

In the study, it was determined that teacher candidates encountered issues such as interdisciplinary integration, planning phase, lack of creativity, lack of experience, time constraints, and material procurement during the design phase. Some candidates stated that they did not have difficulties in the design phase, especially due to the benefits of group work and their manual skills. Candidates have suggested solutions such as guidance teacher support, increasing engineering courses, and more practice to overcome these challenges. When the relevant literature is examined, similar findings are encountered. In the study by Hacıoğlu et al. (2017), it was found that teacher candidates struggled with areas such as time management, classroom management, and designing appropriate problems during the engineering design process. In the study by Harman and Yenikalaycı (2021), it was found that teacher candidates expressed negative opinions about activities related to the engineering design process due to their time-consuming nature and difficulty in implementation. Similarly, in the study by Öner Armağan, Metin, and Atalay (2023), teachers implementing STEM activities expressed that these activities were quite time-consuming and that they could not adhere to the time allocated in their lesson plans.

In integrating science into STEM applications, most teacher candidates feel inadequate. The difficulties experienced in discipline integration and engineering applications are the main reasons affecting this situation. While there are candidates who feel more comfortable integrating mathematics and technology, the challenges in engineering integration become more pronounced. In the relevant literature, Ecevit et al. (2024) concluded that despite teacher candidates' willingness to integrate the STEM approach into their lessons, they need practical training on the STEM approach. In the findings of Isma'il et al. (2019), it was found that science teachers have a high level of proficiency in STEM integration at the middle school level. In Cebesoy's (2024) study, teachers emphasized the necessity of integrating science with different disciplines and the importance of incorporating the STEM approach into science classes.

In the study, it was determined that science teacher candidates were sufficient in integrating mathematics. The teacher candidates stated that the reason for this is due to their knowledge competencies. Similar results are found in the literature. In the study by Stohlmann, Moore, and Roehrig (2012), it was emphasized that teachers' mathematical knowledge and experience are important in STEM integration. In a similar vein, Yıldırım (2017) stated that one of the reasons why science teacher candidates feel sufficient in integrating mathematics into interdisciplinary science teaching is due to their mathematical knowledge adequacy. It has been observed that the reason teacher candidates do not feel sufficient in integrating mathematics is due to the lack of interdisciplinary integration practices.

Participants have mentioned that they feel sufficient in integrating technology into STEM applications. When we look at the studies conducted, we see similar results. The study by Muthmainnah and Putri (2023) has shown that teachers perceive themselves as competent in applying technological pedagogical content knowledge in STEM education. In Vieira et al. (2023), teachers stated that they found themselves ready to integrate digital technologies.

In the study, it was observed that science teacher candidates felt inadequate in integrating engineering into STEM practices. This finding is supported by relevant studies (Srikoom and Faikhamta, 2018; Kelley and Knowles, 2016; Cunningham and Carlsen, 2014; Liao and Tse, 2024). In the study by Kelley and Knowles (2016), it was stated that teachers had difficulty making connections between STEM disciplines. In the study by Cunningham and Carlsen (2014), it was noted that teachers who would be involved in engineering instruction were not adequately prepared and that sufficient opportunities related to engineering were not provided in their professional training. In the study by Liao and Tse (2024), it was found that teachers were inadequate in integrating engineering into STEM practices.

In the study, teacher candidates suggest increasing training for teachers, offering elective courses, and assigning homework related to real-world problems to enhance the effectiveness of STEM practices. In the relevant literature, similar to this situation, Aslan and Bektaş (2019) suggested the introduction of elective or compulsory courses in the science teaching undergraduate program to provide STEM education.

In conclusion, the effects of STEM education on the self-efficacy of science teacher candidates are multifaceted and complex. These findings necessitate the more effective incorporation of the STEM approach into teacher education programs and the provision of support to enhance teacher candidates' self-efficacy in these areas.

Recommendations

- According to the study findings, it has been observed that teacher candidates have difficulty establishing interdisciplinary integration. To overcome this difficulty, it is suggested to offer an elective course themed around STEM.
- The study found that the teacher candidates' competencies in the engineering discipline were low. Therefore, it is recommended to offer elective courses to develop the engineering skills of teacher candidates.
- According to the findings obtained from the study, it is observed that teacher candidates feel inadequate due to their lack of practical experience. To prevent this inadequacy, it is recommended to organize workshops and seminars for teacher candidates.

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Author Information

Mehmet Enes Kahraman	Fulya Öner Armağan
https://orcid.org/0009-0009-7907-2878	http://orcid.org/0000-0003-2085-1390
Erciyes University	Erciyes University
Turkiye	Turkiye
	Contact e-mail: *fulyaner@yahoo.com*

Appendix. Interview Questions

1. Do you consider yourself sufficient in STEM applications? Why?

Survey: Can you explain in which areas/levels you feel sufficient or insufficient?

2. Do you have difficulty in the design phase of STEM applications? Why?

Survey: At which stage do you experience the most difficulties? Why? What are your proposed solutions regarding this?

3. Do you consider yourself sufficient in integrating science into your STEM applications? Explain with reasons.

a. Do you consider yourself sufficient in integrating Mathematics into your STEM applications?

b. Do you consider yourself sufficient in integrating technology into your STEM applications?

c. Do you consider yourself capable of integrating Engineering into your STEM applications?

4. What can be done to increase the effectiveness of STEM applications? What are your suggestions on this matter?