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Preface

STEM education has taken its place in science education in our country as well as all over the world. With this study, STEM education, which is an integral part of science education, is an integral part of the teacher candidates' scientific creativity, 21^{st} Century skills and their impact on scientific process skills were investigated. It is thought that this research will be a source for researchers, science teachers and graduate students working in this field. We wish you pleasant reading with the hope that the book will contribute to the studies in this field.

Balıkesir, 2025

Assoc. Prof. Dr. Ayberk BOSTAN SARIOĞLAN

Buse GÜLER

Contents

1. Introduction

The 21st century is an age in which the races of invention, production and technological development are rapidly gaining momentum. Humanity, on the other hand, has been in change and development since the day it existed, and has constantly strived to renew itself. With this renewal effort, individuals are expected to be in a position not only to consume information but also to produce it (Erdamar, Demirkan, Saraçoğlu and Alpan, 2017). For these reasons, considering the requirements of the 21st century, there have been radical changes in many areas. One of these radically changing areas is the field of education. With the radical changes in education systems, students are expected to be creative, critical and analytical thinking individuals. What is important in today's education policies is not only the success of students' exam grades. It is also important for students to acquire 21st century skills such as problem solving, communication, collaboration, creative, analytical, and critical thinking (Becker and Park, 2011). When we look at the traditional understanding of education, the acquisition of these skills is insufficient. For this reason, many countries have switched from traditional teaching to modern teaching approach. The traditional understanding of education is a rote and authoritarian model in which the teacher is active in the centre and the student is a passive listener. The teacher is the only source of knowledge and prefers straight narration. The student learns information by memorization but does not associate it with everyday life. Every student is expected to learn with the same method and technique. At the point of evaluation, the result is important, not the process. The only criterion for the success of the student is the grades he receives because of the exam. In the student-centred contemporary education approach, the teacher is the guide. The student, on the other hand, is the one who thinks, criticizes, researches and questions in the process. The student accesses the information himself and is active in the process (Alatlı, 2014). The information is associated with other disciplines and daily life. At the point of evaluation, it is important how the process is managed and what it adds. At the same time, the contemporary understanding of education allows to develop problem-solving, creative and critical thinking skills. Each student is unique and learns with different methods and techniques (Işık and Yenice, 2012). The important thing is not the success in the exam results, but how the student structures the information. In this context, it is seen that the expectations of the 21st century can be met in a student-centred, contemporary education approach.

Especially in recent years, there is a need for manpower that can think, criticize, produce, question and create in the fields of science, technology, engineering and mathematics (Yıldırım and Altun, 2015). At this point, many new teaching methods and techniques have emerged. One of them is the STEM-based learning approach. STEM (formed from the first letters of the English words Science, Technology, Engineering, Mathematic) education draws attention (Bybee, 2013). In our country, the abbreviation STEM has been adapted to Turkish and named as STEM

(Akyıldız, 2020). Within the scope of this study, the abbreviation STEM will be used.

STEM is an interdisciplinary approach that combines science, technology, engineering, and mathematics under one roof. It aims to identify the existing problem situations of individuals and to produce appropriate solutions to these problem situations. One of the main goals of STEM education is to prepare students for real-life problems. The student should be able to transfer the knowledge learned in the course to daily life and transform theoretical knowledge into practice. In this way, the student can easily analyse and solve the problem situations that he encounters in his daily life.

In order for STEM education to be implemented effectively and for students to be trained in this direction, it is important to design STEM education as a process that starts in the pre-school period and continues until higher education (Akgündüz, Aydeniz, Çakmakçı, Çavaş, Çorlu, Öner and Özdemir, 2015). STEM education adopts a student-centred approach as it aims at the active participation of students and looking at problems from different perspectives (Türk, 2019). Student-centred education is an understanding in which students are enabled to discover information themselves and are more active in the learning process and take responsibility for their learning (Yağan, 2022). In STEM education, students learn by doing research and questioning, away from memorization. In this process, students are offered the opportunity to connect with real-world problems, thus enabling them to gain lifelong learning skills. STEM education gives students the chance to look at the world from a different window by giving them different perspectives.

Just as science begins with curiosity and questioning (Savran Gencer, 2015), the sense of curiosity is the basis of everything a person questions in his daily life. In this way, people try to understand the why and how of the events, phenomena or situations they see around them. At this point, we encounter the importance of STEM education. It is aimed to raise a student profile that can transform the knowledge learned in STEM education into products. It is important for students to make the right decisions, to research, examine and question the decisions they make. In STEM education, the individual should learn by doing and living and be able to use technology actively.

Raising individuals who research, think, criticize, produce creative ideas, use technology, and explore nature is among the main goals of STEM education. At this point, teachers have a great job. Teachers who will apply STEM should focus on integrating the disciplines of Science, Technology, Engineering and Mathematics, and should be able to transfer achievements or concepts by associating them with daily life problems. In addition, they should be able to pose interesting and intriguing problem situations, adopt inquiry-based learning approaches that put students at the centre, and encourage students to work collaboratively by working as a team. At the same time, he must be well versed in an engineering design process and cycle that leads to the development of a product or process to solve problem situations.

1.1. Purpose of the Research

In the 21st century world, technology and science are developing rapidly. It is imperative that education systems keep up with this development. In this context, the transition from traditional teaching approaches to contemporary teaching approaches has started in education. With this transition, it is important for the student to learn by doing and living and to take an active role in the process (Kesici, 2009). The STEM learning approach aims to develop students' interdisciplinary thinking skills. At the same time, it is aimed to improve students' academic success and 21st century skills.

Especially in recent years, studies on STEM education have become quite widespread in our country (Pehlivan and Uluyol, 2019). However, with the impact of technology and science, which are carried forward every day, studies on STEM education need to gain momentum. With these studies, people have information about what STEM education is and understand its importance. Thanks to a qualified STEM education, as students develop, their impact on science increases. In this process, they are expected to become active individuals who contribute to science. In addition, with the interdisciplinary perspective of STEM education, students are allowed to contribute to the research and inquiry processes.

The aim of this study is to examine the effect of the STEM approach on scientific creativity, scientific process skills and 21st century skills of 3rd grade science teacher candidates within the scope of the "Science Teaching Laboratory Applications I" course. In the application carried out within the scope of this study, pre-service teachers were asked to prepare STEM-based lesson plans in line with the determined science subjects. The study is designed to take place in a collaborative learning environment. As a result of this process, pre-service teachers created lesson plans by combining science, technology, engineering and mathematics disciplines and presented them in the classroom environment. It is also thought that the study will contribute to the critical thinking, problem solving, and interdisciplinary perspective skills of teacher candidates with STEM education.

1.2. Importance of Research

What today's education system expects from students is not to learn information by memorizing, but to learn by structuring information (Güneş, 2015). At the same time, developing students' critical and creative thinking and problem-solving skills is one of the goals of today's education system. At this point, with STEM education, students' ability to recognize real-life problems and produce solutions gains importance. It is important for teachers to understand the importance of STEM education to integrate STEM education into lessons efficiently.

This study aims to contribute to the professional development of pre-service teachers by examining how pre-service science teachers experience STEM education and its effects on scientific creativity, scientific process skills and 21st century skills within the scope of the "Science Teaching Laboratory Applications I" course.

Moving STEM education from theoretical knowledge to practice can help pre-service teachers plan more effective and innovative lessons in the classroom environment in the future. At the same time, STEM education offers pre-service teachers the opportunity to associate science subjects with real-life problems. Teacher candidates are not only science; At the same time, they gain thinking skills integrated with technology, engineering and mathematics. It is expected that pre-service teachers who receive STEM education will develop a more positive attitude towards science lessons and increase their self-confidence in the teaching profession.

In addition, this study is effective in providing 21st century skills such as collaborative work, problem solving, creative and critical thinking of pre-service teachers by providing a practical model for STEM education. These skills are important both for the professional development of pre-service teachers and for the development of their future students. At the same time, STEM education allows them to develop scientific process skills such as making observations, predictions, and hypothesizing. Thanks to these skills, it becomes easier for pre-service teachers to provide a multi-faceted perspective to their students in the future. In this respect, the study will not only support the individual development of teacher candidates but will also contribute to the students' quality STEM education in the long run.

1.3. Problem Statement

In this study, an answer to the question "What is the effect of STEM education on scientific creativity, scientific process skills and 21st century skills of 3rd grade science teacher candidates within the scope of science teaching laboratory applications I course?" is sought.

1.4. Sub-Problems

Within the scope of the research, the following sub-problems were determined.

1. Is there a significant difference between the scientific creativity pre-test and post-test scores of 3rd grade science teacher candidates using STEM applications in the science teaching laboratory applications I course?

2. Is there a significant difference between the pre-test and post-test scores of the scientific process skills of 3rd grade science teacher candidates using STEM applications in the science teaching laboratory applications I course?

3. By using STEM applications in science teaching laboratory applications I course, 3rd grade science teacher candidates will be able to learn 21st century skills (critical thinking, problem solving, creative thinking, etc.) Is there a significant difference between pre-test and post-test scores?

2. Theoretical Framework

In this section, explanations about the STEM learning approach, instead of STEM in science education, the introduction of STEM to education, the introduction of STEM to Turkey, academic success with studies on STEM in Turkey and abroad, the use of STEM in laboratory applications, creativity, critical thinking, scientific process skills, information about 21st century skills are included.

2.1. STEM Learning Approach

STEM is an acronym for Science, Technology, Engineering, and Mathematics (Marrero, Gunning and Germain Williams, 2014). STEM education is a learning approach that combines these four disciplines under one roof. In STEM education, students seek solutions to real-world problems, think critically, come up with creative ideas, and produce innovative solutions. In this way, the student profile needed by the 21^{st} century is created. Thus, students are equipped to cope with the challenges posed by the rapidly changing world.

STEM education encourages the use of science, enabling students to make sense of the world and produce innovative solutions to problems related to daily life. Students make sense of nature, discover intriguing events, and develop attitudes that support lifelong learning.

The science course allows students to question scientific concepts and understand these concepts through observation (Yılmaz, 2023). In this way, students gain problem-solving skills and offer more solution-oriented approaches. In this process, students also manage their own learning. At the same time, in science where engineering and technology are intertwined, it can increase the interest of students in these fields, and students who have interest and talent in this field can be discovered and guided while making career choices in the future. With science, students are curious about the events around them and ask the question of why. In this way, students' sense of curiosity develops. At the same time, they develop a positive attitude towards the lesson and grow up as investigative individuals.

With the use of technology in STEM education, it is ensured that scientific knowledge is applicable in daily life. At the same time, research to solve problems creates opportunities for the development of new ideas. In addition, it is possible to conduct experiments in science in a virtual environment, to model designs, to design posters, etc., with the use of technology. It acts as a bridge that combines technology, science, engineering and mathematics in STEM education. This facilitates integration between disciplines. In addition, thanks to the rapidly developing structure of technology, it increases the ability of students to produce innovative solutions.

The engineering discipline in STEM education covers the process of product design and development. At the same time, he seeks creative solutions to real-world problems using science and mathematics, connecting science, technology and mathematics by turning solutions into products. In this way, students' problem-solving skills improve, encourage creativity and innovation, and offer solutions that can be applied to real life. As a result, theoretical knowledge turns into practice with the discipline of engineering. With engineering projects, students develop their creativity and develop their critical and analytical thinking skills. Students use their analytical thinking skills in the design, planning, and testing stages by using engineering design steps (Harman and Yenikalaycı, 2021).

The discipline of mathematics, on the other hand, covers basic elements such as measurement, calculations, ratio-proportion, graphs, equations, 2D and 3D modelling, geometric and algebraic methods in STEM education. In the process, it has an important role for the successful continuation of the project. For example, it is active in recognizing and solving problems, analysis and interpretation of data. In other words, the discipline of mathematics is the key point of STEM education. Because mathematics provides the basic tools and equipment necessary to understand, interpret and apply other disciplines. With the discipline of mathematics, students' critical, creative and analytical thinking skills are strengthened. It is also effective in embodying abstract concepts.

2.2. The Introduction of STEM in Education

In recent years, the need for different learning and teaching approaches has become a necessity in the changing world order. For this reason, teachers should turn to contemporary learning approaches rather than just providing content to students. Here, we come across the STEM learning approach. The traditional education system generally tends to convey content and neglects to learn in a hands-on way. In this case, students are incomplete in developing skills such as creative and critical thinking, problem solving, and reasoning. When the problems that exist today are examined, it is important to find interdisciplinary solutions at the point of looking for solutions. At the same time, students need to know how to use this information and solutions. STEM education can be shown as an effective learning approach to meet this need by combining four disciplines under one roof. STEM education is effective in achieving permanent learning by enabling students to find solutions to problems and learn by researching and questioning (Avan, Gülgün, Yılmaz and Doğanay, 2019). It contributes to the development of students' skills such as creative and critical thinking, research-inquiry, problem solving, cooperation and reasoning. Individuals with these qualities are equipped with 21st century skills that form the basis of STEM education. It is extremely important to train the manpower needed today in this direction. While STEM education benefits individuals to gain 21st century skills, it also directly affects the competition between countries. Keeping up with this competition is important for social development (Arslan and Arastaman, 2021). As global competition among developed countries increases, information races have gained momentum along with economic needs. Countries have also had to reform their education systems to become leaders in the fields of science, technology and engineering. However, individuals are expected to be competent in the fields of science, technology, and engineering. Educating competent individuals, especially in the field of STEM, is important for accelerating the growth and development of countries. Digital innovations, which are rapidly developing and entering our lives in the 21st century world, have transformed the labour market into a new one. To keep up with this change and development, the education systems of the countries seem to turn to approaches that can be applied such as STEM and integrate technology into education (Ay and Seferoğlu, 2020). The emergence of new professions arising from fields such as robotic coding and artificial intelligence also aims to provide these competencies in education reforms.

STEM has an important place in the scientific, technological and economic development of societies. These areas not only increase global competition but also support sustainable development (Ayverdi, Börekci, Avcu, Girgin, Özatlı, Satmaz and Yalçınkaya Önder, 2024). Especially with the support of science to technology and engineering, the labor shortage in these sectors has increased the importance and investments given to STEM education. Competition among developed countries has also affected educational curricula. Scientific researches, technological developments, engineering applications are gaining momentum under the guidance of STEM. STEM is an influential factor for development and economic growth not only among developed countries but also in developing countries. By focusing on STEM education, it is aimed for students to develop critical thinking, problem solving, reasoning, creative thinking, questioning skills and to transfer the information they have learned to different situations (Güder and Gürbüz, 2018).

STEM education also creates opportunities for women and disadvantaged groups. For example, UNESCO conducts global campaigns to direct girls to STEM fields (Taş and Bozkurt, 2020). In this way, it is aimed to prevent the perception that exists in the society and to encourage women in scientific fields. Girls who participate in these campaigns at an early age are given the opportunity to see different career opportunities by getting to know STEM education. Thanks to the efforts made to encourage women to keep up with this development and change, it will make a significant contribution to scientific and technological progress.

At this point, it is seen that the role of teachers in STEM education is very important. Teachers, like students, should have an interdisciplinary perspective and adopt a student-centred education approach. STEM teachers should encourage students to research and question, allow students to discover information and produce solutions, support collaborative learning, know how to use technology and encourage students in this regard, and integrate creative and critical thinking into their lessons (Acar, 2020). For this reason, STEM education should be given more place in the education of teacher candidates, and it is important for teachers to keep their knowledge up-to-date by continuing in-service trainings. Because STEM teachers are not only role models who convey knowledge but also teach students how to use it.

Looking at these benefits of STEM education, it first emerged in the United States (Kol and Karslı Baydere, 2023). In the period when the competition between countries gained momentum, STEM had to be integrated into education in line with the USA's need for educated individuals in the fields of science, technology, engineering and mathematics (Gencer, Doğan, Bilen and Can, 2019). It has been observed that this innovation, which started in the USA, has been adopted in other countries and added to education programs (Ekici, 2023). Today, many countries use STEM education to prepare students for professions in science, technology, engineering and mathematics and support economic growth.

2.3. The Ground of STEM in Science Education

Science education is in an important position for students to understand the problems they encounter in daily life and to make sense of the world. In the Maarif Model Science Course Curriculum, it is aimed to train individuals who have the life skills needed by the age and can use their scientific process skills effectively, who can comprehend technology integration, who are entrepreneurial and career-conscious in the field of science (MEB, 2024).

In recent years, daily life problems have been frequently integrated into science lessons in terms of motivating students towards science lessons, attracting their interest and attention to the subjects, or determining their prior knowledge levels (Yılmaz and İnce Aka, 2022). For this reason, it has been necessary for teachers to use different teaching methods and techniques in the lessons to familiarize the students with the new order. One of these methods and techniques is the STEM learning approach.

STEM is a learning approach that combines science, technology, engineering and mathematics disciplines under one roof. With STEM education, students become aware of the problems they may encounter in daily life and produce creative solutions. In addition, it creates an opportunity for each student to develop their thinking skills by brainstorming. In STEM education and science lessons, it is important for students to transfer information to different situations rather than learning by memorizing information. At the same time, STEM education, which encourages students to seek solutions to real-world problems, contributes to the development of 21st century skills. In the courses taught with STEM education, students create hypotheses, collect data, analyse these data and bring a scientific answer to the problem by reaching the conclusion by using the steps of the scientific method. In this way, science courses will be able to provide more efficient and effective participation. With STEM education, it becomes possible for students to put theoretical knowledge into practice and develop their imagination. For this reason, it is seen that science and STEM education is a course that attracts students' attention and interest, seeks solutions to real-world problems and increases motivation (Bakırcı and Kutlu, 2018). To increase the impact of STEM education, curricula should be organized appropriately, and teachers should have the necessary competencies in this direction (Aydeniz, 2017). At this point, the fact that teachers are open to development and have a desire to learn will increase the efficiency of STEM education. It is insufficient for the teacher to have only a good level of knowledge of the field. At the same time, it is extremely important that he knows how to transfer his knowledge of the field. In addition, students should be an educator who contributes to the development of problem-solving, critical and creative thinking skills, gains different perspectives and can use technology effectively, and is open to change. It is important for students to explore and make sense of the world around them by establishing relationships between the fields of science, technology, engineering and mathematics. Students are expected to discover theoretical knowledge and transform it into practice, and teachers are expected to guide students in this process. In this way, not only academic success is affected by STEM education, but also offers lifelong learning opportunities to individuals (Bozdemir Yüzbaşıoğlu, Aşkın Tekkol and Karabulut Coşkun, 2022).

As a result, by supporting science with STEM education, the interests and abilities of the students in the professions they will choose in the future are determined and it is possible to direct them to these fields. Science lessons become more colourful and remarkable, and the student's motivation for the lesson is ensured. By connecting with real-world problems, it contributes to the development of interdisciplinary thinking skills.

2.4. Introduction of STEM to Turkey

The introduction of STEM into Turkey has started to attract attention, especially in recent years. With STEM education, which contributes to the development of 21st century skills, it aims to enable students to think of science, technology, engineering and mathematics disciplines together. With the acceleration of technological developments and reforms in education, it has been integrated into the curriculum and the curriculum has been blended. For example, engineering design skills are included in middle and high school curricula (Okulu and Oğuz Ünver, 2021). Especially in science, technology, design and mathematics courses, STEM education-based studies are included. These practices have been added to the textbooks, and it has been seen that the students receive education in this direction. In this way, students' interdisciplinary perspective has been developed. To implement STEM education effectively and efficiently, they encouraged teachers to participate in various in-service programs (Çınar and Terzi, 2021). Because it is necessary to have teachers who introduce STEM education to students. In addition, science fairs and technology races are organized to increase the awareness of STEM education in our country. This awareness are strengthened with projects such as TÜBİTAK and TEKNOFEST (Güneş Koç and Kayacan, 2022). It is aimed to develop students' creative thinking and problem-solving skills by making STEM-oriented projects. Schools have been provided with tools such as smart boards and tablets to support technology. As the courses were taught with the integration of science, technology, engineering and mathematics, students with talent or interest in these fields were discovered. In their study, Sarıgül and Çınar (2021) found that after receiving STEM education, students' interest in engineering and science fields increased and their thoughts of building a career in these fields were formed.

With the addition of STEM education to the curriculum in Turkey, engineering and design processes have come to the fore in science courses. By teaching students the engineering design process, it is aimed to provide them with the skills of recognizing the problem, producing innovative solutions, and analytical thinking. In 2016, the Ministry of National Education (MEB) officially defined STEM with the comprehensive "STEM Education Report". In the report, recommendations were made for the transition to STEM education. Then, the 2017-2018 curriculum was updated, and STEM education was included in the program. Engineering and design skills have been added to the curriculum and the books have been enriched with activities where students can develop their problem-solving, critical and creative thinking skills.

In the Turkish Century Maarif Model, which will be presented to the public in 2024, a radical change in education is aimed. With the model, a student-centred, skill-oriented, contemporary education in which technology is integrated is aimed. It is not only for the academic development of students; at the same time, it is important to contribute to their social, emotional and moral development (MEB, 2024). The model supports the development of students' skills such as problem solving, collaboration, creative and critical thinking. In particular, the design-skill workshops in the model reveal the main purpose of STEM education. STEM education establishes an interdisciplinary connection and enables students to seek solutions to real-world problems. With these workshops, it is possible for students to concretize abstract knowledge and turn theoretical knowledge into practice. Here, students develop their hand skills and learn by doing and experiencing. For this reason, the STEM approach is an important tool for the implementation of this model.

With the implementation of a qualified education system, able to think creatively, critically and analytically in the country; Individuals with developed problem-solving skills are raised. At this point, STEM-based teaching leads to scientific and technological developments. In this way, it provides social development in the long run.

2.5. Studies in STEM Education in Turkey

When the literature is examined, studies on STEM education in Turkey have gained momentum, especially in recent years. In the research, different dimensions of STEM education have been examined and its integration and effects on our education system have been discussed. In this section, some of the studies on STEM education in our country are included.

Since 2010, there has been an increase in the number of articles and theses on STEM education in our country. Especially in 2014, this increase became more pronounced (Çavaş, Ayar, Bula Turuplu and Gürcan, 2020).

Studies conducted with pre-service teachers,

In this section, researches conducted with pre-service teachers and dealing with different dimensions of STEM education are included. Studies that can examine the effect of different research methods were preferred.

In the study published by Yıldırım and Altun in 2015, 83 science teacher candidates constituted the sample group.

Within the scope of the study, it is seen that pre-service teachers are divided into experimental and control groups and work throughout the fall semester. In the experimental group, STEM education was given, and in the control group, the lessons were taught in accordance with the program. As a result of the research, a significant difference was observed in favor of the experimental group in which STEM education was applied. As a result of the study, it was determined that STEM education was effective in improving the academic success of students.

In the study conducted by Aslan and Bektaş in 2019, the views of science teacher candidates on STEM education were examined. In the study, it was determined that pre-service teachers could associate science with other disciplines, know what STEM is, and think that increasing STEM studies would be beneficial. They also stated that they have infrastructure problems and financial inadequacies to provide STEM education. As a result of the study, it was presented as a suggestion that STEM education should be given while training teachers in education faculties.

In their study, Ergün and Kıyıcı (2019) investigated the metaphorical perceptions of 69 3rd grade science teacher candidates about STEM education. As a result of the research, pre-service teachers produced 50 valid metaphors. With these metaphors, it was seen that pre-service teachers had positive thoughts about STEM education. At the same time, it has been determined that STEM education provides learning by doing, allows raising individuals who develop solutions to problems, and they see STEM as an interdisciplinary approach. In addition, it has been observed that pre-service teachers do not have a negative opinion about STEM education.

In the study of Şahin (2019), which examines the awareness, attitudes and opinions of science teacher candidates about STEM applications, a significant and positive increase in the attitudes and awareness of pre-service teachers about STEM applications; A positive change has been observed in views on STEM applications.

In their study conducted in 2024, Oskay Güven and Ünal Çoban evaluated the effect of argumentation-based STEM activities on the argumentation skills and competencies of 4th grade teacher candidates in STEM subjects. As a result of the research, it was determined that argumentation-based STEM activities positively affected the argumentation skills of pre-service teachers. Another result of the research was that argumentation-based STEM activities also positively affected STEM competence.

Studies with teachers

In this section, studies on the awareness and opinions of teachers, academicians and school administrators on STEM education are examined.

In the studies conducted by Karakaya, Ünal, Çimen and Yılmaz in 2018, they determined the awareness of science teachers about STEM education. In this direction, the "STEM Awareness Scale (STEM)" was used. As a result of the study, it was seen that a significant difference was found in the awareness of STEM education of science teachers according to gender, professional experience, in-service/course/seminar, education level, and there was no significant difference according to the number of students in the class and the type of school they worked in.

In the studies carried out by Çınar and Terzi in 2021, they revealed the opinions of teachers trained in STEM and the problems they experienced. As a result of the study, it was seen that teachers thought that STEM approaches increased students' problem solving, creativity, critical thinking and interdisciplinary thinking skills. At the same time, they stated that teachers integrated technology and engineering design skills into the lessons. In addition, it has been observed that teachers face the problems of material supply, inability to use time efficiently, and lack of knowledge against other disciplines.

In the study published by Gürbüz and Kahveci in 2021, they aimed to determine the views of graduate students in science education on STEM. As a result of the study, they think that STEM has a positive effect on students, provides meaningful learning, and provides skills such as problem solving, critical and creative thinking. In addition, it was observed that the students' knowledge level about STEM was not sufficient.

In the study conducted by Taktat Ateş, Saraçoğlu and Ateş (2022), they examined the views on STEM education by using the interview technique with six academicians working in the field of science in the faculty of education of four different universities. As a result of the study, it has been determined that it has a positive effect on students' life skills, effective learning is provided, STEM activities arouse interest and curiosity, improve professional experience, increase academic success and student motivation, and positively affect 21st century skills such as problem solving, decision-making, design thinking and creative thinking. At the same time, they stated that STEM education requires a lot of time, is expensive, is not suitable for some course contents, is difficult to practice in crowded classrooms, the level of knowledge about STEM is low, and cooperation is incomplete.

In the studies of Tezcan Şirin, Tüysüz and Kaval Oğuz (2022), who examined teachers' views on STEM activities in secondary school science textbooks, it was seen that teachers knew the definition of STEM, could integrate the activities in secondary school textbooks into their lessons, and considered themselves sufficient in terms of field knowledge and pedagogical field knowledge. In addition, they stated that the activities in the books were related to daily life but did not see it as suitable for STEM education, did not provide an interdisciplinary perspective, and the questions at the end of the activities were insufficient. In the study, it was suggested to extend the course hours, to improve the laboratory environments in schools, to reduce the number of students in the class, and to organize the activities in the books in accordance with the curriculum.

In their study, Atalay and Öner Armağan (2023) examined the awareness and opinions of STEM education teachers about STEM education. As a result of the study, it was seen that teachers thought that STEM was connected to other disciplines. It has been determined that teachers mostly integrate STEM with simple machines, electricity and energy subjects. They also stated that students gained meaningful and permanent learning and improved their self-confidence with STEM studies. Teachers also mentioned the lack of equipment in schools and the lack of prior knowledge of students.

In the studies carried out by Karaduman and Eti in 2023, they determined the opinions of 4 educators working in the STEM education centre about STEM education. As a result of the study, it was found that educators made suggestions about the characteristics of STEM education, its objectives, current STEM practices, the difficulties encountered in STEM education, the functioning of the STEM centre, and STEM education.

In their study, Metin, Güler and Çevik (2023) examined the views of 6 STEM-educated science teachers about 21st century skills. At the end of the research, it was determined that teachers were able to define STEM, provide permanent learning, and develop problem-solving, critical and entrepreneurial skills. At the same time, it has been observed that they associate 21st century skills with the technology discipline the most, and that the inclusion of 21st century skills in science education has negative effects rather than positive effects. As a reason for this, it was determined that the teachers had difficulties in time, material supply and adaptation of the subjects.

In the study published by Güleç Çiftçi and Şentürk in 2024, school administrators' awareness of STEM education was examined. As a result of the study, it was determined that school administrators have a positive attitude towards STEM education. It is foreseen that if the necessary tools, infrastructure and qualified teachers are provided, school administrators will be able to have awareness in STEM education. Along with these deficiencies, it has been observed that school administrators' awareness in STEM education is low.

Studies in which teachers and teacher candidates are examined together,

In this section, there are studies in which teachers and teacher candidates take part together and their opinions and awareness about STEM education are examined.

In the study conducted by Timur and İnançlı in 2018, the opinions of teacher candidates and teachers about STEM education were consulted. As a result of the research, it was seen that teacher candidates had more knowledge in STEM education than teachers. In addition, it has been determined that both teachers and teacher candidates have a desire to learn about STEM education.

In her study, Kaya (2019) examined the views of science teachers and teacher candidates on STEM education and made a needs analysis. In the study, teachers and pre-service teachers evaluated STEM education, the contribution of STEM education to students, themselves about STEM education and the environmental conditions required for STEM education. As a result of the study, it was seen that teachers and teacher candidates gave close answers to each other. They stated that the positive aspect of STEM education is quite high and that it is a necessity for students, and that they are lacking in this regard.

In their study, Baran, Baran, Aslan Efe and Maskan (2020) examined the STEM awareness levels of science teachers and pre-service teachers in terms of different variables. As a result of the study, it was seen that the STEM awareness levels of pre-service teachers were lower than teachers. Faculties of education are expected to continue their studies on this issue.

Studies carried out at primary and secondary school level,

In this section, studies on STEM education carried out at primary and secondary school levels were included. It was examined in terms of different dimensions such as student attitude, motivation, scientific process skills, creativity, and interest in STEM professions of STEM education. At the same time, various application methods (coding, game-based learning, full learning model, etc.) Its impact on STEM education has been investigated.

In their study, Yamak, Bulut and Dündar (2014) examined the effect of STEM activities on 5th grade students' scientific process skills and attitudes towards science. As a result of the research, it was determined that STEM activities positively improved students' scientific process skills and attitudes towards science.

In their study, Gökbayrak and Karışan (2017) made applications on STEM disciplines with 6th grade students and examined student opinions. As a result of the study, students stated that STEM activities benefit in many ways and that they want to make more progress in these areas.

When the study conducted by Keçeci, Alan and Kırbağ Zengin in 2017 was examined, applications related to game-supported coding, fun science activities, and coding education were made in STEM education with 30 5th grade students. The study was carried out by using the attitude scale and student diaries related to educational game-supported coding learning. As a result of the research, a significant difference was found in the educational game-supported coding of the students. In the student diaries, it was seen that the students learned by having fun and found it easy.

In the study published by Yıldırım and Selvi in 2017, the effect of STEM education and full learning model on seventh grade students' academic achievement, inquisitive learning skills, motivation for science lesson, attitude towards STEM education and permanent learning was examined. It has been determined that STEM education and full learning model have a positive effect on academic achievement and motivation for science lesson, but STEM education and full learning model do not develop a positive effect on STEM attitudes and inquisitive learning skills.

In their study, Balçın, Çavuş and Topaloğlu Yavuz (2018) examined the attitudes of secondary school students towards STEM, their interest in STEM professions and them in terms of various variables. As a result of the research, it was seen that the students had positive attitudes towards STEM. When the students' attitudes towards STEM were examined in terms of variables such as gender, grade level, and the location of their schools, it was seen that there was no significant difference between them. In addition, it was seen in the study that students had positive attitudes towards professions in STEM fields. It was determined that there was a significant difference between students' interests in professions in STEM fields and grade level variables. At the same time, it was observed that there was no significant difference between students' interests in professions in STEM fields, their gender, and the locations of their schools. It was determined that there was a positive and high correlation between students' attitude scores about STEM and their interest scores about professions in STEM fields.

In the study conducted by Benek and Akçay in 2018, 120 students at the 5th, 6th, 7th and 8th grade levels determined their mental structures related to STEM designs using the STEM drawing form. As a result of the study, it was seen that the students drew the most in the category of "helping with housework" and the least in the categories of "space" and "lens". When the drawings were examined according to the gender variable, it was seen that female students drew the most in the "helping housework" category, while male students drew the most in the "car" category. At the same time, when the students were asked about the drawings they planned to make, they stated that they could draw mostly by using technology and the least by using mathematics.

In their study, Gülen and Yaman (2018) examined how 20 6th grade students used argumentation activities in STEM education. As a result of the examination, it was seen that the students were able to cooperate in group work and use STEM disciplines in the process.

According to the study conducted by Gülhan and Şahin in 2018, they investigated the preferences of 107 students studying at the 5th grade level regarding professions in STEM disciplines and the reasons for these preferences. Students were asked whether they would like to have a profession in one of the fields of science, technology, engineering and mathematics in the future. When the data were analysed, it was seen that most male and female students preferred science and mathematics fields, most of the female students did not want the field of technology and engineering, and male students wanted the field of technology but did not want the field of engineering.

In the study of Gülhan and Şahin (2018), one of the studies conducted in the context of STEM education, they examined how students' scientific creativity would change when STEM applications were integrated into the science course. As a result of the study, it was determined that it had little effect on the scientific creativity of 5th grade students towards STEM activities. At the same time, it has been observed that the most reflective thinking layer of scientific creativity contributes to the development.

In their study conducted in 2018, Karakaya, Avgın and Yılmaz examined the interest of secondary school students in STEM professions in terms of different variables. According to the results obtained, there was a significant relationship between gender, academic achievement and technology use in students' interests in STEM professions, and there was no significant relationship according to the position they lived in for a long time. In addition, it has been determined that the discipline with the highest level of interest of the students is technology.

The research of Yıldırım and Selvi (2018) in the literature revealed important findings on STEM applications. In the study, they examined the opinions of 56 7th grade students about STEM applications used in teaching science courses. The study was completed in a total of 8 weeks, 4 hours a week. As a result of the research, it has been found that students develop positive attitudes towards STEM practices, gain meaningful learning and contribute to 21st century skills.

In the study conducted by Herdem and Ünal in 2019, they examined the relationship between the level of tendency towards scientific values and their interest in STEM-oriented professions of 200 secondary school students. As a result of the research, it was concluded that the relationship between these two was positive and moderate. In addition, it has been observed that the sub-dimensions of curiosity and creativity are effective in determining the interest in STEM professions. While there was no significant difference between the interests in STEM professions when the grade levels were examined, a significant difference was found in the field of Engineering and Technology when looking at the gender.

In their study conducted in 2019, Karakaya, Yantırı, Yılmaz and Yılmaz examined the views of 4th grade students on STEM activities. In line with the results obtained, it was seen that the students associated STEM activities with daily life problems. It has also been found to affect students' courses, career preferences and communication skills. At the same time, it has been observed that some problems such as time, lack of knowledge and lack of materials have arisen in the implementation of the courses.

In their study, Öner and Özdem Yılmaz (2019) examined the relationship between the attitudes and perceptions of STEM-related problem solving and questioning learning skills of 646 students studying in the 5th, 6th and 7th grades of secondary school. As a result of the study, it was seen that there was a positive correlation between students' perception of problem-solving skills and their attitudes towards STEM, and there was a neutral correlation between students' problem-solving skills and STEM perceptions. At the same time, there was no significant difference between students' perception of inquisitive learning skills and their perception of STEM, but a positive correlation and significant difference were found between their perceptions of inquisitive learning skills and their attitudes towards STEM.

In their 2020 study, Bahşi and Açıkgül Fırat examined the effect of STEM applications on 8th grade students' scientific process skills, scientific epistemological beliefs and science course achievements. The study progressed in the normal process with STEM applications in the experimental group and in the control group. As a result of the study, a significant difference was found in the pre-post-test results of the scientific process skills experimental group, while there was no significant difference in the pre-post-test results of the control group. According to the results of the scientific epistemological beliefs scale, there was no significant difference between the experimental and control groups in the pre-test results, but a significant difference was found in favour of the experimental group in the post-tests. According to the results of the science achievement test, there was no significant difference in the pre-post-test results of both the experimental and control groups.

The study, published by Bulut in 2020, examined the STEM attitudes of middle school students. As a result of the study, it was found that there was no significant difference according to the type of school the students studied, but there was a significant difference according to the number of books they read per month, whether they were active in projects or not, and their academic achievement.

In their study, Doğan, Aydın and Kahraman (2020) examined the perceptions of STEM education on students' problem-solving skills. They worked with 60 eighth grade students as an experimental and control group for 2 lesson hours a week, for a total of 6 weeks. As a result of the research, a significant difference was found in favor of the experimental group. Based on the research, it has been concluded that students can improve their scientific inquiry skills and problem-solving skills by integrating STEM education into the lessons.

According to the study conducted by Gazibeyoğlu and Aydın in 2020, they determined how students' attitudes towards the course changed and their views on STEM education by processing the seventh-grade force and energy unit with STEM education. When the data of the "Science Attitude Scale" were analysed, a significant difference was observed in favor of the experimental group supported by STEM education. They also stated that the students of the experimental group learned the subjects better by having fun.

In their study, Kahraman and Doğan (2020) examined the motivations of STEM education for students to learn science and determined student opinions. A total of eight weeks were studied with 98 eighth grade students, 3 control and 3 experimental groups. As a result of the study, it was concluded that STEM education significantly affected the motivation of the students towards science learning in favour of the experimental group. At the same time, it has been observed that students learn by having fun.

In 2020, Pekbay and his colleagues examined the views of seventh grade students on activities for STEM education.

The study continued for 6 weeks and continued with STEM activities prepared on thermal insulation. As a result of the research, the activities were found fun and educational by the students. In addition, it was observed that it developed students' creativity, self-confidence and imagination, and it was determined that it encouraged students to work in groups. At the same time, it was observed that some of the students could not work together comfortably and had difficulty in designing products.

Sarı and Katrancı (2020), who examined the perceptions of fourth-grade students towards STEM activities, obtained important data based on students' opinions in this context. As a result of the research, it was found that students have positive opinions about STEM applications, are effective in developing skills, are intriguing, fun and increase motivation for the lesson. In addition, it was observed that the students had difficulties in design and product creation and material preference.

In their study, Gündüz Bahadır and Özay Köse (2021) examined how scientific creativity and students' interest in STEM professions would change with the integration of STEM education into science lessons. As a result of the courses taught as an experimental and control group, it was observed that scientific creativity differed significantly in favor of the experimental group. In addition, a significant change has been observed when looking at how students' interests in STEM professions have changed.

In his study conducted in 2021, Kırılmazkaya determined the attitude levels of secondary school students towards STEM education and examined their understanding of engineering. Mixed research design was used in the study. An interview form was used to determine engineering understandings and a STEM attitude scale was used to determine STEM attitude levels. As a result of the research, it was seen that the students developed a positive attitude towards STEM education and there was no significant difference in terms of gender variable. In addition, it was determined that the students had sufficient knowledge about engineering. At the same time, suggestions were made that STEM disciplines should be included more in the curriculum and that STEM corners should be built in classrooms and schools.

In their study conducted in 2021, Öztürk İrtem and Hastürk determined the perceptions of secondary school students as scientists and engineers. In the study, 545 students participated in the "Draw a Scientist" test and 521 students participated in the "Draw an Engineer" test. As a result of the study, it was seen that the students drew male as the gender of scientist and engineer. As a working environment, it was determined that they drew laboratories for scientists. In addition, although there are many achievements related to STEM disciplines in our current curriculum, it has been noticed that students have a traditional mindset.

In the study published by Şanlı and Somuncuoğlu Özerbaş in 2021, they worked with 70 secondary school students. They examined the effect of STEM activities on students' attitudes and motivation. As a result of the research, it was seen that there was no significant change in the attitudes of the students towards STEM education. At the same time, it was determined that STEM education did not show a positive change in students' research and in-class motivation, and no significant change in collaborative work, performance and communication. It has been determined that STEM education generally develops a positive attitude towards science education, but it has been stated that this effect is low.

In their study conducted in 2022, Karabulut and Timur developed a scale to determine the attitudes of secondary school students towards STEM applications in science lessons. It has been determined that the scale developed because of the research can be used as a valid and reliable measurement tool. When the attitudes of the students towards STEM education were examined with the developed scale, there was no significant difference between the genders, but a significant difference was found at different grade levels.

In the research of Şentürk Özkaya and Bostan Sarıoğlan (2023), which is one of the current studies in the field of STEM education, they carried out an activity on teaching the existing concepts of mass and weight with the STEM circle about 7th grade Force and Energy. In the activity, students were divided into groups and designed models with Tinkercad and printed them on a 3D printer. As a result of the study, it was seen that all groups were able to create models, but they were insufficient to solve the problem they created.

Sarıca and Bostan Sarıoğlan (2024), which are about STEM-based teaching of Force and Movement, were carried out with 6th grade students at secondary school. In the study, they investigated the effect of STEM education on the academic achievement and creativity of secondary school students. 25 students in the experimental group were taught STEM-based teaching, and 20 students in the control group were taught traditionally. As a result of the study, it was found that the academic success of the experimental group with STEM-based teaching increased and their creativity levels improved.

Preschool and early childhood studies,

In this section, there are four studies conducted in preschool and early childhood. In this context, general trends in practice, opinion and literature were examined.

In their study conducted in 2018, Akgündüz and Akpınar evaluated STEM education in terms of students, parents and teachers. The study was carried out for 8 weeks with the participation of 20 students aged 5 years. As a result of the study, it is seen that students have achieved science and mathematics achievements, and 21st century skills (critical thinking, creative thinking, collaboration, etc.) have developed. In addition, it is seen that these thoughts are supported by the opinions received from parents and teachers.

In the studies of Polat and Bardak, (2019) attention was drawn to the use of STEM education in early childhood and the studies on this subject were examined. As a result of the study, it was stated that the more STEM education is given in preschool education, the more it will support the next levels. In addition, studies on STEM education covering primary and preschool education have determined that it is not yet sufficient.

In their study conducted in 2021, Abanoz and Deniz in the literature examined the opinions of 24 volunteer preschool teachers about science activities suitable for the STEM approach. After the examination, it was seen that the teachers did not have knowledge about STEM education and defined it as a method. Teachers also stated that science activities provide learning by doing and living and support scientific process skills.

In her study, Bursa (2022) examined the effect of inquiry-based STEM practices on preschool students' scientific process skills. In the study, which was carried out in the form of an experimental and control group, STEM activities were applied to the experimental group. As a result of the study, it was reached that the scientific process skills of the experimental group improved with the effect of STEM applications.

Studies with gifted students,

In this section, there are three studies for STEM education carried out with gifted students, which include hands-on activities and allow students to develop different skills.

In their study, Özçelik and Akgündüz (2017) applied STEM education to gifted/gifted students. A total of 2 weeks of 32 hours were worked with 25 gifted/gifted students who had not received STEM education before. As a result of the study, it was seen that the students gained the skills of creative and critical thinking, working collaboratively, and communicating.

In the study conducted by Barış and Ecevit in 2019, they developed STEM activities for 11 gifted students and applied these activities to two groups for 5 weeks, a total of 40 hours. At the end of the study, it was found that the students developed a positive attitude towards science, gained scientific process skills, and were able to look at it from an interdisciplinary perspective.

In the study published by Kalik and Kırındı in 2022, they examined the implementation of STEM activities in out-of-school learning environments and the attitudes of gifted/gifted students towards STEM education and their entrepreneurship skills. As a result of the study, it was determined that there was a significant difference in the attitudes and entrepreneurship skills of gifted/gifted students towards STEM education.

Studies examining STEM education and methods,

In this section, different learning and teaching approaches used in the implementation of STEM education are included.

In his study, Özsoy (2017) examined the applicability of creative drama on STEM education. As a result of the study, it has been concluded that creative drama can contribute to the implementation process of STEM.

In their study in 2018, Güven, Selvi and Benzer worked with 5th grade students. Within the scope of the study, they examined the development of students in the 7E learning model-centred STEM activity on the achievements of measuring strength. Although this study slightly increased the mean grade achievement, there was no significant difference between the academic achievements of the students.

Content analysis and literature reviews

In this section, a total of 10 studies published between 2017 and 2025 are included, and these studies are in the type of literature review and review for STEM education.

In the study conducted by Çolakoğlu and Günay Gökben in 2017, the studies on STEM education in the faculties of education in our country were examined and suggestions were made at the point of improvement. As a result of the surveys, the awareness and interest levels of the faculty members in the faculties of education about STEM were high, but it was determined that there was not enough implementation in this regard and suggestions were made that it should be improved.

In their study, Seren and Veli (2018) compared the 2005, 2013 and 2017 science curricula. While comparing, engineering applications in STEM education, the suitability of achievements for STEM education, the suitability of course hours for STEM education, the vision of the programs, and interdisciplinary relations were examined. As a result of the examination, it was seen that the content for STEM education was not included enough in the science curriculum, and studies were added to the 2017 curriculum under the name of science and engineering applications. Over the years, there has been an increase in the curriculum and the number of course hours to increase student participation. While exemplary activities were included in the 2005 curricula, it was concluded that exemplary activities were not included in the 2013 and 2017 curricula.

In the study, which was analysed by Aydın Günbatar and Tabar in 2019, it is seen that 67 articles published in the field of STEM in our country were examined according to some criteria. These were examined by criteria such as participant, study type and design, data collection tools, variables and types, whether STEM education is seen or not, time allocated to STEM, which approaches are used to teach the courses, STEM components, recognizing real-life problems, and suitability for education. As a result of the examinations, it was seen that 40% of the studies were worked with students and 38% of teacher candidates, 50% of the studies were qualitative case studies, and the most studied subjects were opinions about STEM and attitudes towards STEM education. In addition, STEM training was given to the participants in 26 of the studies; It has been determined that these studies are insufficient in terms of integrated STEM education, activities and measurement and evaluation.

In their study, Gencer et al. (2019) reviewed the literature on the integration of education programs and discussed theoretically integrated STEM approaches. As a result of the study, the researchers could not reach a common decision about the degree of integration between the disciplines and the way they are integrated for integrated STEM education.

Çavaş et al. (2020), who scanned the literature in the field of STEM education, analysed articles and graduate theses published in Turkey from 2010 to the present. With the findings obtained from the articles and theses examined, it is expected that studies on STEM education in our country will increase.

According to the study published by Kalemkuş in 2020, he examined experimental research published between 2014-2019 on STEM education. As a result of the study, it was determined that the researches were especially concentrated in 2018, and many of their studies were master's thesis. Most of their research was conducted with middle school students. Academic achievement, problem solving, attitude towards the course, scientific process skills were studied.

Eren and Dökme (2022), who examined 40 empirical studies conducted in Turkey between 2014-2020 on STEM education in the context of science, made significant contributions to the literature. As a result of the examination, it has been seen that STEM studies in the field of science have increased in recent years and easily accessible laboratory materials are used. In addition, it has been determined that the use of robotic applications related to the technology discipline is low, and the programs in the robotic applications used are low. It has also been determined that engineering design processes are preferred, and it has been observed that students' academic achievements, scientific process skills, problem solving, motivation, self-confidence, STEM-based interests and attitudes are positive.

In the studies of Tekin Bozkurt and Yıldırım (2023), a total of 16 theses were examined using STEM education and classroom keywords. As a result of the theses examined, it has been seen that most of the theses in the field of STEM are at the master's level and have been published since 2018. In addition, it has been determined that the theses are mostly studied in the field of science.

In the study conducted by Gümüş and Eroğlu in 2024, the effect of STEM education on academic achievement, STEM attitudes and interest in STEM professions in science education was examined. As a result of 86 studies examined, a strong effect of STEM education on academic achievement and occupational interest was found, and a moderate positive effect on STEM attitudes. These results indicate that STEM education is effective in science education.

In her study, Batur (2025) examined the postgraduate theses on STEM applications for secondary school students written in the field of science education in Turkey between 2016-2023. 9 of the theses examined are doctoral theses and 52 are master's theses. It has been observed that most of the studies were done at the 7th grade level and were mostly related to the "Force and Energy" unit. In addition, it has been observed that STEM applications are generally planned for 6 weeks. As a result of the study, more research should be done at the doctoral level, 8. It is suggested that more space should be given to grade level studies and non-physics subjects.

2.6. Studies in STEM Education Abroad

In this section, some of the studies on STEM education abroad are included.

In their study, Kennedy and Odell (2014) highlighted the increasing importance of STEM education due to the impact of the global economy. In the study, the implementation of STEM education in a way that covers all students and the importance of supporting teachers in these issues are mentioned. In addition, it has been mentioned that STEM education develops students' innovative thinking and problem-solving skills with an interdisciplinary perspective.

In the study conducted by McDonald in 2016, the contribution of Science, Technology, Engineering and Mathematics disciplines in STEM education was examined; It evaluated student participation and the role of teachers in STEM education. Within the scope of the research, 237 studies were examined. As a result of the study, it was concluded that for students to continue their interest in STEM, it is necessary to focus on secondary school periods; We believe that STEM increases students' interest and motivation, improves 21st century skills and supports academic success; It has been found that training qualified teachers benefits STEM education.

In the study published by Popa and Ciascai in 2017, the experiences of students studying at universities in Romania about STEM education and their views on the engineering profession and skills were examined. Looking at the results of the study in which 110 students participated, it was seen that most of the students attracted the attention of STEM disciplines since their middle and high school periods, and they were affected by the STEM courses they took in the past while choosing a university.

In their study published in 2018, Bogusevschi, Muntean, Gorji and Muntean evaluated the impact of technology-supported STEM education developed within the scope of the NEWTON project on 5th grade students in terms of information learning, motivation and use. This application has included various topics including Atmosphere, Geosphere, Biosphere, and Atmosphere. While these topics were presented to the experimental group by an expert group through NEWTELP, which was developed within the scope of the NEWTON project, they were presented to the control group by their own teachers with traditional methods. A knowledge test was applied before and after each lesson. In addition, post-class usability and motivation tests were conducted to determine students' interest and motivation for STEM subjects. As a result of the study, it was seen that the courses supported by technology positively affected the students' interest, motivation and knowledge levels of STEM subjects.

Nuangchalerm (2018), who examined the views of primary school STEM teachers in Thailand on STEM education and interdisciplinary learning, obtained important findings. 120 teachers participated in the study. As a result of the study, teachers' views on STEM education differ according to the characteristics of the schools. In addition, it has been observed that teachers need more information to better understand the impact of STEM education.

In their study published in 2020, Kiazai, Siddiqua and Waheed examined the difficulties that may be encountered in the implementation of the STEM approach and the extent to which the teacher training program can intervene in these difficulties. The sample of the study consisted of 202 pre-service teachers. As a result of the study, it was stated that some difficulties were encountered in the implementation of the STEM approach, but it was stated that teacher training programs were important in overcoming these difficulties. The challenges are as follows: Infrastructure problems, lack of teacher training, time, student motivation and government support.

Rifandi, Rahmi and Indrawati (2020), which examines the perceptions of pre-service teachers towards STEM education, focused on the field of science and mathematics in the Indonesian context. It was concluded that pre-service teachers' perceptions of STEM education were generally positive. Most participants stated that STEM education should be included in the curriculum and emphasized that STEM is a relationship with daily life. They also stated that it would take time in terms of implementing STEM education in lessons and asked for a solution to this.

In their study, Seage and Türegün (2020) investigated the effect of learning methods blended with traditional science teaching on STEM achievement on primary school students in regions with low socioeconomic status. As a result of the study, a significant increase in students' STEM achievement was determined in favor of the blended learning approach.

In their study published in 2022, Arnado, Pene, Fuentes and Astilla examined the attitudes of 71 STEM teachers towards science teaching and their self-efficacy beliefs in performing laboratory practices. As a result of the examination, it was seen that STEM teachers had a high level of self-confidence in their self-efficacy beliefs about science teaching and laboratory practices, and developed positive attitudes about science teaching. In addition, a low level of positive relationship was found between STEM teachers' laboratory self-efficacy beliefs and their attitudes towards science teaching and self-efficacy beliefs.

The study, published in 2021 by Dare, Keratithamkul, Hiwatig and Li, investigated how K-12 level science teachers comprehend STEM education and implement it in their classrooms. 19 teachers participated in the study. As a result of the study, all teachers emphasized that STEM develops 21st century skills and that STEM should be taught in relation to science, technology, engineering and mathematics disciplines. Teachers stated that they used STEM subjects in their lessons by associating them with real-world problems. In addition, it was seen in the research that there are teachers who have different ideas about STEM disciplines. It is thought that this can help teachers prepare high-quality professional development experiences.

Permanasari, Rubini and Nugroho (2021), who evaluated the perspectives of science teachers and students' attitudes within the scope of STEM education, obtained important results. As a result of this study carried out in Indonesia, it was seen that science teachers generally understood STEM education well, but most of them did not integrate it into the lessons. It has also been found that most of the students are unfamiliar with STEM education.

In their study, Sirajudin, Suratno and Pamuti (2021) examined the effect of STEM education on developing students' creative thinking skills. As a result of the study, it was found that STEM education positively affects students' creative thinking. However, although the creative thinking skills of the students differed according to the initial level, the test results were below the expectations.

The study, published in 2023 by Lafifa, Rosana, Suyanta, Nurohman and Astuti, determined the impact of STEM education in science learning on developing students' 21st century skills. As a result of the literature reviews, it has been found that STEM education is effective in developing students' 21st century skills such as communication, creativity, critical thinking and cooperation. The most addressed skill is critical thinking.

In their study, Martynenko, Pashanova, Korzhuev, Prokopyev, Sokolova and Sokolova (2023) analysed 23 articles on STEM education. Looking at the results of the analysis, it has been determined that Turkey is the country that provides the most data. Teachers' STEM attitudes were generally found to be positive. It has been observed that teachers working in private schools' support STEM more than teachers working in public schools. It has been observed that the STEM attitudes of undergraduate students are positive and high school students are at medium level. Gender, on the other hand, did not have much effect on STEM attitudes.

In their article published in 2023, Menon, Shorman, Cox and Thomas examined how pre-service teachers develop their STEM teaching self-efficacy by parallel processing of 3 courses (science and engineering, mathematics and technology method courses). As a result of the study, pre-service teachers showed significant positive increases in their self-efficacy in STEM teaching from the beginning to the end of the semester, and pre-service teachers' confidence in STEM teaching increased. In addition, positive changes in pre-service teachers' concepts and attitudes about STEM were also determined, At the same time, thanks to the parallel processing of three courses, it contributed positively to the development of pre-service teachers' self-efficacy in STEM teaching.

In their study, Thomas and Larwin (2023) examined the impact of STEM education on academic achievement at the secondary school level among underrepresented minority groups (black, Hispanic, and first-generation students). As a result of the study, it was determined that the majority of students who participated in STEM education in secondary school were more successful. Underrepresented minority students, in particular, benefit more from STEM education. However, it has been observed that these students do not participate in STEM education. For this reason, it is thought that it is inevitable to prevent success.

In the 2024 study, AlAli and Wardat examined how science teachers incorporate STEM practices into their lessons and the challenges they face. As a result of the study, it was seen that teachers generally developed a positive attitude towards STEM education, but they also faced difficulties such as insufficient physical resources and time problems. At the same time, it has been stated that STEM education increases students' participation in the lesson.

There are many STEM-oriented studies carried out abroad in the literature. Considering the diversity of these studies, the unique aspect of this research is that it will contribute to the literature with its special subject and application context.

2.7. Academic Achievement

With STEM education, students are not only provided with scientific and technical skills but also contribute to the development of their academic success (Turgutalp, 2021; Cooper and Heaverlo, 2013). STEM education is effective in concretizing theoretical knowledge by transforming it into practice and providing permanent learning. Because it improves students' problem-solving, critical and creative thinking skills.

In STEM education, the focus is on daily life problems, and it increases the success of students, especially in mathematics and science courses, in the process of analysing and solving complex problems (Acar, Tertemiz and Taşdemir, 2020). At the same time, in STEM education, students work in cooperation with the fields of science, technology, engineering and mathematics while solving a problem (Aslan Tutak, Akaygün and Tezseven, 2017). In this way, students learn by discovering the connection between the lessons, which positively affects academic success. Through skills such as critical and creative thinking, students have a better grasp of complex problems. The development of these skills in STEM education also contributes to academic success (Çimen, 2021; Wolf, 2019; Herdem and Unal, 2018). In STEM education, the fact that students are at the centre by actively participating in the lessons increases the permanence of the information in the memory (Yıldırım and Selvi, 2017). Because the student is active in the process, he learns by doing and experiencing.

In order for STEM education to increase success, the process must be well managed. At this point, the quality and competence of the teacher is important. Teachers need to synchronize students, have field knowledge adequacy, course methods and technical knowledge, and use technology effectively (Yıldırım, 2018). At the same time, the quality of the curriculum, its well-designed and feasible nature, and its real-world problems are important. At the point of implementation of STEM education, the physical needs of schools should also be met. For example, it is also thought that if the necessary technological infrastructure is provided, the academic success of the students will increase (Kılınç and Karabudak, 2024). The fact that families are conscious and supportive in STEM education is also effective in increasing student success.

Various projects are being developed for STEM education. One of the projects is the science centres, which have been implemented with the work of TÜBİTAK and local governments since 2015. Such centres increase students' interest in STEM disciplines and allow them to pursue careers in these fields (Bulut, Birgili, Koçoğlu, Gülünay and Baş, 2024). At the same time, the opening of STEM-based kindergartens and high schools aims to increase academic success by enabling students to look at them from an interdisciplinary perspective. Providing

STEM education at an early age enables the student to grow up with this perspective. It is predicted that the use of technological applications such as artificial intelligence, augmented reality, and virtual reality will also make the learning process more remarkable and interactive (Yacan, Yacan, Türkkan, Taşdemir and Kahmiran, 2024). In this way, it increases academic success.

The PISA and TIMSS exams are an important tool that examines the impact of STEM education. One of the reasons for the success of countries that implement STEM education in these exams is the structure that deals with daily life problems with an interdisciplinary perspective. Turkey's investments in STEM education will also increase performance in international exams. TIMSS measures what students know, and PISA measures what they can do with this information (Cerit Berber, 2015). This situation is in line with the main goals of STEM education. STEM allows students to adapt knowledge to different situations, develop problem-solving, analytical, creative and critical thinking skills. Students gain these skills at an early age thanks to STEM-oriented curricula. At the same time, if the STEM approach is disseminated in education curricula, it increases individual and social development. Therefore, it is important to focus on STEM education to increase success in national exams (Koyuncu and Kırgız, 2016).

2.8. STEM Education in Laboratory Applications

The most important point that distinguishes science from other disciplines is that science attaches importance to experimentation, observation and discovery. At the same time, it gives the student the chance to develop their creative, critical and questioning aspects, to establish and test hypotheses and to interpret the results (Kırpık and Engin, 2009). Laboratory studies in which theoretical knowledge is turned into practice, interdisciplinary integration is ensured, and solutions to problem situations are sought are important in science teaching. In laboratory applications, students embody abstract knowledge and gain learning by doing and experiencing (Kubat, 2015). It encourages active learning, transforming the student from a passive receiver to an active participant. In this way, it contributes to the development of students' reasoning, interpretation, critical thinking, creative thinking, reasoning skills, problem solving, cooperation and 21st century skills (Üçüncüoğlu and Bozkurt Altan, 2018). At the same time, students' motivation for the lesson increases and the lesson becomes more remarkable (Yazıcı and Kurt, 2018).

Students develop scientific process skills such as hypothesizing, designing experiments, making observations, collecting data, analysing data, and evaluating results in science courses (Öztürk and Ural Keleş, 2023). When faced with an unexpected result, students use critical thinking and problem-solving skills to question cause-effect relationships and try to find possible solutions to the problem. For this reason, carrying out the science course with laboratory applications provides permanent and meaningful learning to students (Dinçol Özgür, Odabaşı and Erdoğan, 2017; Acarlı and Dervisoglu, 2018). At the same time, the laboratory environment is suitable for students to work in groups. In this way, students learn to work collaboratively, participate in scientific discussions, and improve their communication skills (Ceylan and Feyzioğlu, 2018).

The laboratory environment facilitates the implementation of STEM education. In laboratory studies, it enables students to learn by doing and experiencing in the disciplines of science, technology, engineering and mathematics. It aims to produce solutions to real-life problems, to develop hypotheses based on scientific knowledge, and to develop design-oriented thinking skills. If STEM education is supported in laboratories, students' 21st century skills and scientific process skills develop (Karslı Baydere and Şahin Çakır, 2019) and provide a working environment where technology is integrated into lessons. At the same time, students experience engineering design processes, make measurements and can mathematically analyse the data they reach. In this way, a learning environment is created in which students embody abstract knowledge (Kocakülah and Savaş, 2011).

Laboratory applications where STEM courses will be taught should focus on developing mathematics and problem-solving skills, and how to teach these different technologies to students collaboratively. In this way, laboratory applications can create a positive classroom environment by exchanging ideas among students, encouraging teamwork and facilitating the use of technology. In addition to all these, STEM laboratories develop a sense of curiosity, enable a positive attitude towards science, and create an opportunity for students to learn by doing and experiencing (Böyük, Demir and Erol, 2010). In this way, it enables students to be more interested and motivated by science, technology, engineering and mathematics. At the same time, it supports students to be better prepared for their future professional lives. As a result, with the effective application of laboratory applications, it becomes a complementary element of science courses and becomes a learning that supports the development of students' 21st century skills.

Below are some studies carried out in the laboratory environment that contribute to the teaching process.

In their study, Sürücü, Özdemir, Bilen and Köse (2013) examined the attitudes of pre-service science teachers towards laboratory applications according to gender and grade levels. As a result of the Laboratory Attitude Scale, no significant difference was determined according to the gender of the teacher candidates. When the attitudes of pre-service teachers were examined according to the 3rd grade and 1st grade levels, a significant difference was found in favor of the pre-service teachers in the 3rd grade.

In 2014, Pekbay and Kaptan carried out their studies to increase the awareness of pre-service science teachers about the effectiveness of laboratory applications. For this purpose, they applied different activities to pre-service teachers. As a result of the study, it was found that laboratory applications were effective in increasing the awareness of pre-service teachers.

In the study published by Karslı Baydere and Şahin Çakır in 2019, the effect of laboratory applications on the scientific process skills self-efficacy beliefs of science teacher candidates was examined. Laboratory applications based on scientific process skills were applied in the experimental group, and traditional laboratory applications were applied in the control group. Looking at the results of the study, there was no significant difference between the self-efficacy beliefs of the experimental and control groups. However, it has been stated that laboratory applications on scientific process skills positively affect the development of pre-service science teachers' skills such as observation, designing experiments, and interpreting data.

In the study conducted in 2021, Çetin and Cengiz investigated the effect of pre-service science teachers' processing of tissues in a laboratory environment in biology class on their academic achievement and attitudes. In the study, an experimental design with pre-test/post-test control group was used. As a result of the research, a significant difference was observed between the pre-service teachers in the experimental group in favor of the control group who taught with traditional methods. In this way, it was determined that the experimental group of pre-service teachers made more concrete learning.

As a result of the study conducted by Yurttaş Kumlu (2022), it was found that pre-service science teachers think that the studies carried out in the laboratory are beneficial.

In Akkış's master's thesis in 2024, she investigated the self-efficacy and concerns of science teacher candidates in the biology laboratory. As a result of the research, it was found that laboratory applications showed positive improvement in the self-efficacy of pre-service teachers and decreased their anxiety levels.

2.9. Creativity

Creativity in STEM education; It is integrated with analytical thinking, critical thinking and problem-solving skills, providing students with the opportunity to produce innovative solutions. In traditional education systems, lessons are generally based on memorization and repetition, but in STEM education, it is important for students to learn by doing, to develop original ideas, and to think innovatively (Altunel, 2018). In the traditional understanding of education, it focuses on the transfer of knowledge and teaches by memorizing information. Lessons are usually teacher-centred, and since students are in the position of listeners, their participation in the lessons is limited. All students learn the same information with the same methods (Karol, 2023). For these reasons, the traditional understanding of education focuses on standard answers and limits creativity instead of encouraging students to be creative (Saraçoğlu and Duran, 2009). In the contemporary understanding of education, students play an active role in the learning process. Students research, question and generate new ideas. Students learn to learn throughout their lives, and skills such as critical thinking, collaboration, analysis, and creative thinking are at the forefront. It enables individuals to develop in all aspects. At this point, it is seen that the traditional understanding of education prevents creativity because it is in a rote system (Özerbaş, 2011).

In STEM education, students are expected to combine theoretical knowledge with different disciplines and turn it into practice. In this way, it is seen that students develop creative thinking. Students' synthesis of information from different disciplines forms the basis of creative thinking. In STEM education, students identify real-world problems and seek solutions, design and implement their own projects, embody abstract information by using their imagination and make it meaningful by transforming it into a product (Pekbay, Saka and Kaptan, 2020). At these stages, creativity is an important part of STEM education.

Creativity is related to all disciplines of STEM education. In science, creating new hypotheses, thinking from different perspectives, designing innovative experiments; in technology, the development of ideas, unlimited possibilities, exploring a variety of programs; in engineering, designing new products, building functional structures, developing different solutions (Bozkurt Altan and Tan, 2022); In mathematics, developing problem-solving methods, discussing with flexible thinking (Gür and Kandemir, 2006), analytical and abstract thinking provide creative thinking. In this way, students develop a positive attitude and curiosity about the lesson.

With creative thinking, students bring together different disciplines. In this way, they gain the skills of recognizing and solving problems, critical thinking, research and questioning

(Özkok, 2005). A student with advanced creative skills not only uses the information he has learned but also blends that information and finds various solutions by looking at it from different windows. At the same time, they combine the knowledge they have learned with their own experience and knowledge and make original ideas. In this way, it has been observed that students' creativity skills positively affect academic success (Sarıca and Bostan Sarıoğlan, 2024; Güldemir and Çınar, 2021; Şentürk Özkaya and Bostan Sarıoğlan, 2023).

Teachers strive to support students' creativity and encourage them to think and question. For example, they present remarkable, intriguing real-world problems and help students design open-ended projects. At the same time, when a learning environment is created where students develop their own ideas and are encouraged during the product creation phase, creativity increases and students' motivation is ensured. In this way, it is possible for students with different talents and interests to discover their individual creativity.

2.10. Critical Thinking

Many definitions of critical thinking have been made in the literature. According to Evancho (2002), critical thinking is defined as the ability of the individual to be determined about what to believe and do, to be able to analyse these decisions, to make conscious judgments in the evaluation process and to express judgments (Kutru and Hasançebi, 2024). When we look at the relationship between STEM and critical thinking, critical thinking, as can be understood from the definition, enables students to develop their skills in analysing, evaluating, interpreting and analysing information. STEM, on the other hand, ensures that these skills can be applied in real life.

In STEM education, students are given complex problems and what is expected from students is to identify the problems in the problems, find different solutions to these problems, and focus on the appropriate solution and move on to the application part. This process develops the basic skills of critical thinking (Kurtuluş, Akçay and Karahan, 2017). In this way, students learn to make logical decisions by analysing data. Since STEM is an approach offered to students with a combination of different disciplines, it contributes to the development of students' critical thinking skills by examining different dimensions of a problem. In this way, students are helped to think more deeply.

STEM education aims not for students to learn information by memorizing, but to learn with research-inquiry, experimentation, and problem-solving skills (Ekmekci, 2022). In this way, STEM education supports critical thinking and makes it easier for students to find solutions to possible problem situations they may encounter in the real world. With critical thinking, the processes of analysing the problems faced by the student, looking at them from a different perspective, interpreting the data and making inferences are used. At the same time, it develops skills such as reasoning, decision-making, and reasoning. STEM is not an approach that only supports students' academic success. It also provides critical thinking skills that they can use throughout their lives (Sönmez and Sağlam, 2025).

In Demirel's 2024 study, he examined the effect of students' critical thinking characteristics on academic success. As a result of the study, it was determined that the academic success of students with high critical thinking skills was also high. STEM education is also an important point in increasing the academic success of students by developing critical thinking skills. Because in this process, students learn by structuring information and develop their logical thinking skills. In this way, the information becomes more meaningful and permanent.

In another study conducted by Asal Özkan and Sarıkaya in 2023, it was observed that engineering design-based activities contributed positively to students' critical thinking skills. Students use critical thinking processes by blending knowledge from science, technology, engineering and mathematics disciplines. In this way, students' motivation and participation in the lesson increases.

2.11. Scientific Process Skills

In STEM education, scientific process skills develop at both basic and higher levels (Taştan Akdağ and Güneş, 2021; Karci, 2018; Ünal and Aksüt, 2021). STEM's interdisciplinary search for solutions to daily life problems enables students to use their scientific process skills. It is seen that these skills develop both theoretically and practically.

Scientific process skills are divided into basic scientific process skills and high-level scientific process skills (Aktaş, Aktaş and Kalaycı, 2020). It is given in Table 2.1.

Table 2.1: Scientific process skills

Basic Scientific Process Skills	High-Level Scientific Process Skills
Making observations	Hypothesizing
Classification	Designing experiments
Measuring	Checking variables
Communicate	Data Analysis
Make a forecast	Evaluating the results
Making inferences	

2.11.1. Basic scientific process skills

2.11.1.1. Making observations

The work of collecting information about the events and situations happening around us with the help of our sense organs is called observation (Koyuncu Ünlü, 2018).

The ability to make observations is at the heart of STEM education. STEM education offers students the opportunity to explore, understand, reason, look critically, look at and solve real-world problems from different perspectives thanks to the ability to make observations.

In science, observation is the basis of experiments. In laboratory courses, students carefully observe a phenomenon or phenomenon and form hypotheses. For example, in a course where the effect of the floor used on the friction force is examined, students observe how far the vehicles moving on different floors travel in a certain time.

When the ability to make observations in the technology dimension of STEM education is examined, observations can be made through many systems such as technological devices, software and simulations. For example, physical phenomena can be observed by examining the onion skin cell with a microscope, virtual experiments can be performed through software or simulations, and many examples can be said, such as examining the stars with a telescope.

When we look at the observation skill in engineering projects, the process of identifying problem situations and seeking solutions to them forms the basis of observation. For example, when designing a house, observing the durability of the model on the model in order to test its usefulness.

In mathematics, the ability to collect data, analyse data and make observations at the point of examining the results is needed. For example, observing trends in graphs in a physics problem is based on this skill.

In STEM education, the ability to make observations is developed with approaches such as project-based learning, laboratory studies, and nature observations. In this way, it contributes to the development of students' problem-solving skills, critical thinking, creative thinking, interdisciplinary connection, analysis, reasoning and reasoning skills.

2.11.1.2. Classification

The process of separating and arranging objects and situations according to some of their characteristics is called classification (Kavak, 2020). Thanks to this skill, students are helped to better understand complex information and identify common features.

When we look at the ability to classify in science, it is an effective method to understand living things by grouping them according to their common characteristics. For example, classification of living things (bacteria, plants, etc.), physical states of matter (solid, liquid, etc.), classification of natural disasters (earthquake, flood, etc.)

Classification in technology, grouping of tools and simulations according to their intended use. For example, a list of applications that can be drawn, a list of websites that can be researched.

Classification in the field of engineering includes the grouping of materials according to their intended use or the separation of systems according to their properties. For example, grouping the materials to be used when a house is to be built, such as concrete, steel, wood.

In the field of mathematics, classification makes it easier to make sense of the relationship between numbers and shapes. For example, when a money account is to be made, the same amounts of money are grouped; Numbers are classified as prime, integer, rational, irrational.

In STEM education, science, technology, engineering and mathematics are brought together and the ability to classify is handled from an interdisciplinary perspective. By establishing a connection between these disciplines, the classification enables students to gain more effective skills in both academic and daily life. There are many tools and methods that can be used to organize information while classifying. These; concept maps, tables, graphs, mind maps, etc.

2.11.1.3. Measuring

The process of measuring and recording the quantitative properties of an object or situation such as length, weight, mass, temperature is called measurement (Ayvacı and Yurt, 2016).

The ability to measure facilitates understanding of real-world problems and supports mathematical and analytical thinking skills. With the use of the right measurement tools and methods, these skills can be effectively assessed.

Measurement is a competency that will be actively used in all STEM disciplines, especially in the field of science and mathematics. At the same time, the ability to measure plays an important role in the concretization of abstract concepts. For example, in the field of science, it is useful for analysing and recording the events that occur during experiments. In engineering design processes, using measurements when constructing a structure can help build a smooth structure. In addition, the ability to measure the durability of the structures is needed at the point of determining it.

In STEM education, measurement skills play an important role in students' understanding, analysing and solving real-life problems. In this way, students' interdisciplinary perspective is strengthened.

2.11.1.4. Communicate

Communication is the process of expressing data with graphics, tables or written texts (Arslan and Tertemiz, 2004). The findings obtained at every stage of scientific processes are expressed using verbal, written, graphical or visual tools. It becomes easier for students to have the opportunity to share the information, observations and data results they have learned. In this way, a positive classroom climate is created; Communication and collaboration between students increases, and students learn to share.

2.11.1.5. Make a forecast

Predicting possible situations that may occur in the future by making use of past situations, observations, inferences and data is called forecasting (Altınok and Tunç, 2013). In STEM education, making predictions strengthens the processes of recognizing and solving real-world problems. It develops students' critical and creative thinking skills. Students predict the outcomes of an event from observations or in the light of available information. In engineering design processes, the usefulness of the prototype is estimated and it is used to determine possible problems and solutions in advance. By using mathematical data, the ability to predict future trends in the solution of a problem develops. From a technological point of view, for example, the ability to predict the performance of a device is used. Students can predict the future consequences of daily life problems, produce alternative solutions, and take precautions. In this way, critical, analytical and creative thinking skills are developed. Gaining this skill encourages students to think with scientific methods.

2.11.1.6. Making inferences

The process of explaining logical conclusions about events by examining observations or data is called inference (Aslan Efe, Bakır, Baysal and Özmen, 2015).

It contributes to the development of students' ability to understand, produce solutions and analyse scientific processes. Students make sense not only of acquiring knowledge, but also of how to use this knowledge. While conducting experiments in science, conclusions are reached by making inferences in the light of observations and data. In technology, inferences are made according to the result of a process made with a system or device. For example, judgments are made in the light of the results obtained because of an experiment with a physics simulation. In this way, the discipline of technology is integrated into education. In engineering design processes, it can make inferences on the effect of any material that can be used on the structure. As a result of the studies, the process of drawing conclusions by analysing the relationships between the data also forms the basis of mathematics. The ability to make inferences enables the observation and analysis of the data to make sense of the information obtained. In this way, students develop decision-making skills in STEM disciplines and are trained as individuals who produce creative, critical and analytical solutions.

2.11.2. High-level scientific process skills

2.11.2.1. Hypothesizing

Verifiable or falsifiable propositions that explain the observations made and whose boundaries are well drawn to be tested are called hypothesis building (Ağgül Yalçın, 2011). Hypothesis formulation is one of the steps of the scientific method. The hypothesis is usually in testable form (Temiz and Tan, 2009).

Students often resort to hypothesis construction to solve the problems they encounter in STEM education. The ability to construct hypotheses enables students to structure information by using it actively. In science, temporary solutions are produced before experiments and observations. Hypotheses are established in technology to predict whether a system will work or not. It examines the effect of results related to a variable in engineering design processes. For example, the effect of the type of material used in the construction of a building on the strength of the structure can be examined. It makes it easier to make predictions on models in a math problem. For example, in a path time graph, as the slope increases, the velocity of the object increases.

When we look at the benefits of hypothesis building in STEM education, it is seen that it is easier for students to understand scientific processes and develop critical and creative thinking skills. It also has a positive effect on problem-solving skills. Students make better sense of events by hypothesizing and produce creative solutions. For example, in science, it makes things easier to create a hypothesis before designing an experiment. In this way, the ability to hypothesize contributes to the development of creative individuals who can think critically in STEM fields.

2.11.2.2. Designing experiments

This skill is the one that gathers all the skills that have ever existed (Turan, 2015). It is called a plan created based on scientific methods to solve events, situations or problems.

In the process of designing experiments in STEM education, students are required to apply, develop and practice the scientific methods they have learned. In education, it is important for students to transform theoretical knowledge into practice.

Especially in science, experiments are designed for students to make sense of and explore the world. It is possible to design experiments even in digital environments. There are many software for these. It is convenient to carry out experiments that cannot be done in the real world in digital environments with the help of software. Students' learning by doing and experiencing is effective in gaining permanent learning. It is also an important factor that students actively conduct experiments themselves in the process.

In engineering design processes, tests and experiments are carried out to develop new projects and solutions. In mathematics, different experiments are designed to determine the accuracy of models and graphs. In this way, abstract information is taught by concretizing.

When the benefits of designing experiments in STEM education are examined, it is seen that students' scientific process skills improve. At the same time, in the process of designing experiments, students' ability to analyse problems according to their dimensions and develop solutions is strengthened. Differently, the positive attitude of the students towards the lesson colours the lesson by enabling them to gain motivation.

2.11.2.3. Checking variables

The ability to control variables is the basis of scientific research and experiments. It is the process of identifying the existing variables in an event, choosing the variables to be kept constant and to change (Dökme, 2005). This skill is used to improve students' analytical thinking skills.

The independent variable is the variable controlled by the researcher. The dependent variable is the variable that changes depending on the independent variable. Fixed variables are variables that are kept constant during the experimental or research process and do not affect the results (Evrekli, 2010).

For example, in an experiment that examines the effect of friction force on different floors, the type of floor (glass, carpet, marble, soil, etc.) is the factor that affects the friction force that is changed in the experiment, that is, it is the independent variable. The dependent variable is the measured variable, that is, the friction force. The controlled constant variable is the constant variable that does not change during the experimental process, that is, it can be the mass of the object, the applied force, the experimental environment, etc.

Controlling variables allows students to understand the process of scientific research and teaches them to work in a systematic way. By analysing variables, it helps students solve complex real-world problems. STEM's interdisciplinary approach allows students to examine different dimensions of problems. The ability to control variables is a factor that develops students both academically and in terms of gaining experience in daily life.

2.11.2.4. Data analysis

The process that helps us to understand the relationships between the data collected because of the studies by organizing and graphing them is called data analysis (Öner, 2025). Data analysis enables students to make sense of and interpret the data collected during their research or experiment.

In science, the analysis of experimental results is carried out to test the validity of hypotheses. Data collected in engineering design processes can be analysed to test the safety, durability, etc. of the structure. In this way, if there is a deficiency anywhere, it can be discovered and improved. Performing mathematical analysis and using statistical methods is a basic tool used in all disciplines of STEM. In addition, graphics and tables can be used in the data analysis process. Data analysis is also carried out with software or simulations by making use of technology.

Students' ability to think about data and produce ideas and solutions strengthens their critical, analytical and creative thinking skills. At the same time, scientific process skills are developed in the data analysis process and prepare students for their professional life in the future.

2.11.2.5. Evaluating the results

With the data obtained because of the studies, the results are questioned, whether the purpose has been achieved and whether a valid and reliable result has been obtained is examined. In addition, it is determined whether alternative solutions are produced, whether there are deficiencies or faulty aspects, and proceeds in this direction. At this stage, students present the results of their projects, thus developing their communication and critical thinking skills. The evaluation phase of the results in STEM education reinforces learning and allows the development of innovative solutions. At the same time, it contributes to the development of creative thinking and analytical thinking, reasoning, decision-making, and problem-solving skills.

In a STEM project, students move on to the process of finding solutions after becoming aware of daily life problems. They then prototype, test their prototypes, and concluded.

2.12. 21st Century Skills

21st century skills are the skills that individuals have the knowledge, skills, and attitudes they need to acquire to be successful in the modern world and keep up with the times (Önür and Kozikoğlu, 2019). While the traditional understanding of education is based solely on content transfer, the contemporary understanding of education is the learning of the individual to transfer the knowledge he has acquired to different situations. Especially in today's conditions where access to information is quite easy, it is important to be able to adapt information to new situations. 21st century skills not only aim to improve academic success but also play an active role in the work and daily lives of individuals. For this reason, education programs need to be updated to improve 21st century skills (Barası and Erdamar, 2021). These skills, known as P21 in the literature; learning and innovation skills are divided into three main categories: information, media and technology skills, and life and career skills (Özer and Tekin Bozkurt, 2024).

Learning and innovation skills: Learning and innovation skills are included in the conscious management of individuals' learning processes, the ability to use the knowledge they have acquired, and the production of creative ideas. In this way, it is ensured that individuals can easily adapt to the changing world order. These skills are as follows: Critical thinking and problem solving, communication, collaboration, creativity.

Information, media and technology skills: Individuals need to be able to use technology well to access information in the most accurate and fast way. Today, information is increasing rapidly, and it is important how to access and evaluate this information. In this respect, it is very important to keep up with the rapidly developing technology to exist in the digital world. These skills are as follows: Literacy in information, media, information and communication technologies.

Life and career skills: These skills have become important for individuals to quickly adapt to the changing world order and manage their own learning. Because in today's conditions, not only technical knowledge is important. These skills, which are important both in school, work and daily life, are as follows: flexibility and adaptability, assertiveness and self-management, social and intercultural interaction, productivity and accountability, leadership and responsibility.

Today's children are a generation that meets technology as soon as they are born, learns computers and their derivatives very easily and integrates them into their lives. The new generation of students, who are 21st century learners, can communicate healthily, access information easily, and meet their needs thanks to technology. They can quickly adapt to the changing world and improve their skills. They can also participate in change in fields such as art, science, and technology.

21st century teachers, on the other hand, are not only providing students with content, but also enriching their learning and teaching processes. The world of the 21st century is changing rapidly. It is a need for teachers to train individuals who will adapt to this process. At this point, teachers should be open to change, interested in technology and willing to learn. At the same time, it should have a student-centred approach and should be in the position of a guide. The teacher, who is in the position of a guide, should get to know the student and guide them by monitoring their development.

Adopting approaches that manage the process by centring 21st century skills in education processes will take education to the next level. In 21st century education, individuals have tended to make sense of life with the opportunities provided by technology. For this reason, STEM education that will increase literacy skills in the field of science and technology has gained importance to meet the needs of countries for 21st century skills (Ulutepe and Dağ, 2024, p.392). By integrating science, technology, engineering and mathematics disciplines, STEM education offers an environment where individuals can develop 21st century skills such as problem solving, collaboration, creative and critical thinking. Students could apply these skills while working on STEM projects. At the same time, most of the skills required for the workforce needed today are directly related to the branches of STEM education. The relationship between STEM education and 21st century skills form the basis of contemporary educational approaches. It prepares students for their future professions and develops their ability to produce solutions to social problems. For this reason, it is extremely important to integrate 21st century skills into STEM education. For example, Laçin Şimşek and Soysal (2022) determined in their studies that STEM applications have positive effects on developing 21st century skills. Similarly, Çetin and Kahyaoğlu (2018) concluded in their study that STEM-based activities increase 21st century skills. In this study, the development of 21st century skills were supported by STEM-based laboratory applications and the development of these skills of science teacher candidates was examined.

3. Method

In this section, there is information about the model of the research, the study group of the research, data collection tools, data analysis and data collection processes.

3.1. Research Model

This study was conducted to examine the effect of STEM applications on scientific creativity, scientific process skills and 21st century skills of 3rd grade science teacher candidates studying at a state university in the Marmara Region within the scope of science teaching laboratory practices I course. Within the scope of the study, a single group pre-test-post-test weak experimental design was used.

In the weak experimental design, a single group pre-test - post-test is applied to the group first, then the planned application is made, the necessary procedures are performed, and then the post-test application is made. The pre-test and post-test consist of tests consisting of the same content applied at different times. This pattern is carried out by examining the difference between the pre-test and the post-test (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz and Demirel, 2024). The process of the study is given in Table 3.1.

Table 3.1: Duration of the study

Week	Content
1st Week	Pre-Test Application
2nd Week	Reproduction, Growth and Development, Photosynthesis, Respiration in Plants and Animals (Energy Conversions)
3rd Week	Cells and Organelles, Heredity
4th Week	Sustainable Living and Recycling, Energy Conversions, Material Cycles
5th Week	Systems
6th Week	Astronomy
7th Week	Constant Speed Motion, Work and Energy
8th Week	Friction Force, Pressure
9th Week	Electricity
10th Week	Matter & Heat, Temperature
11th Week	Optical, Audio
12th Week	Final Test Application

3.2. Working Group

The study group of this research consists of 3rd grade science teacher candidates studying at a university in the Marmara Region in the fall semester of the 2024-2025 academic year. The reason why pre-service science teachers were chosen as the practice group is that the research is related to STEM education and this approach should be integrated with science. In addition, the application group consists of the students during the researcher's advisor. In this way, the research proceeded in a more systematic way. The study was carried out between September 2024 and December 2025 within the scope of the "Science Teaching Laboratory Applications-I" course. The general characteristics of the study group are given in Table 3.2.

Table 3.2: Gender and numerical distribution of pre-service science teachers

Gender	f	%
Woman	25	86.2
Male	4	13.8
Sum	29	100

3.3. Data Collection Tools

The data of this study were collected from 3rd grade science teacher candidates studying at a university in a province in the fall semester of the 2024-2025 academic year. Three scales were used in the study. Before the data were collected, the necessary permissions were obtained from the researchers who prepared the scales and the ethics committee of the university where the application will be made. In the study, the "Scientific Creativity Test" adapted to Turkish by Deniş Çeliker and Balim (2012); The "Scientific Process Skills Test" adapted to Turkish by Savaş (2011) and the "Multidimensional 21st Century Skills Scale" prepared by Çevik and Şentürk (2019) were used.

3.3.1. Scientific creativity test (BYT)

In this study, the Scientific Creativity Test (BYT) developed by Hu and Adey (2002) and adapted to Turkish by Deniş-Çeliker and Balim (2012) was used to determine the scientific creativity levels of pre-service teachers.

BYT aims to measure individuals' creative thinking skills in different dimensions and consists of a total of seven open-ended questions. Hu and Adey (2002) applied the test to 160 students and determined the Cronbach alpha reliability coefficient as .89. This value indicates that the test is highly reliable. In this study, in the pre-test results of 29 pre-service teachers, Cronbach's alpha reliability coefficient was .667; In the final test results, it was calculated as .666. Both values show a moderate level of reliability.

When the seven items in the BYT are examined, it is aimed at unusual uses, problem discovery, product development, imagination, problem solving, experimentation and product design. In the evaluation of the answers given to the questions, fluency, flexibility and originality scores were examined.

The sub-dimensions covering the items in the test, which consists of seven questions, are given in Table 3.3.

Table 3.3: Sub-dimensions of BYT assessment

Item No.	Function in BYT	BYT Evaluation Sub-Dimensions
1	Unusual uses	Fluidity, flexibility and originality
2	Exploring the problem	Fluidity, flexibility and originality
3	Product development	Fluidity, flexibility and originality
4	Daydreaming	Fluidity, flexibility and originality
5	Problem solving	Flexibility, originality
6	Experimenting	Fluency, flexibility, originality
7	Designing a product	Flexibility, originality

3.3.2. Scientific process skills test (BSBT)

In this study, the "Scientific Process Skills Test" (BSBT) developed by Kazeni (2005) and adapted to Turkish by Savaş (2011) was used to determine the scientific process skills levels of pre-service teachers. While developing BSBT, it consists of the skills of identifying variables (7 items), hypothesis formulation (6 items), functional definition (6 items), designing experiments (3 items), interpreting data and graphics (8 items). To increase the number of questions, 7 questions from Temiz's (2010) study on experimental design and hypothesis building skills were added. The test was first applied to 106 pre-service teachers, and the items with an item discrimination index below 0.20 were removed from the test and the total number of questions was determined as 30. The reliability coefficient of the test applied to 106 pre-service teachers by Savaş (2011) was determined as .70. In this study, Cronbach's alpha reliability coefficient was .533 in the pre-test results of 29 pre-service teachers; In the final test results, it was calculated as .732. It was concluded that the pre-test was not reliable, but the post-test was moderately reliable. The distribution of the items in the BSBT to the questions is given in Table 3.4.

Table 3.4: Distribution of the items in the BSBT to the questions

Scientific Process Skills	Items
Specifying Variables	1, 2, 3, 4, 14, 22
Hypothesis Formulation	8, 13, 16, 21, 29
Functional Identification	5, 24, 25, 27
Table and Graph Reading and Interpretation	5, 7, 11, 20, 26
Designing Experiments	6, 9, 10, 12, 17, 18, 19, 23, 28, 30

3.3.3. Multidimensional 21st Century Skills Scale (MPSS)

In this study, to examine the 21st century skills of pre-service teachers, the "Multidimensional 21st Century Workshop" developed by Çevik and Şentürk (2019). Century Skills Scale" (MPSS) was used.

The items in the MPS are intended to determine the views of individuals in the 15-25 age group about 21st century skills. In this context, the scale consists of 41 items and 5 sub-dimensions. These sub-dimensions are "Information and Technology Literacy Skills, Critical Thinking and Problem Solving Skills, Entrepreneurship and Innovation Skills, Career Awareness, Social Responsibility and Leadership Skills" . Of the items, 34 are positive and 7 are negative items. These inverse clauses are Articles 16, 17, 18, 19, 20, 21 and 35. The scale is a Likert-type scale and uses a five-point rating system. Responses that individuals can give to substances; "5= Completely Agree, 4= Agree, 3= No Opinion, 2= Disagree, 1= Strongly Disagree". The lowest score that can be obtained on the scale is 41, and the highest score is 205. A high score indicates that 21st century skills have increased, while a low score indicates that 21st century skills have decreased.

The Cronbach alpha reliability coefficient of the test applied to 640 students by Çevik and Şentürk (2019) was determined as .86. In this study, in the pre-test results of 29 pre-service teachers, Cronbach's alpha reliability coefficient was .932; In the final test results, it was calculated as .928. Both values show a very high level of reliability. The sub-dimensions and number of items in the MPYS are given in Table 3.5.

Table 3.5: Item sub-dimensions and number of items

Item Subdimensions	Item Counts
Information and Technology Literacy Skills Dimension	15 Articles
Critical Thinking and Problem Solving Skills Dimension	6 Ingredient
Entrepreneurship and Innovation Skills Dimension	10 Articles
Social Responsibility and Leadership Skills Dimension	4 Substance
Career Awareness Dimension	6 Ingredient

3.4. Data Analysis

The study was carried out in the fall semester of the 2024-2025 academic year. The study was carried out for 12 weeks with 3rd grade science teacher candidates within the scope of Science Teaching Laboratory Practices-I course. In this process, pre-service teachers prepared STEM-based lesson plans for 10 weeks and implemented them in the laboratory.

SPSS 23.0 statistical program was used for the analysis of the data obtained from BYT, BSBT and ÇBYYBÖ used in the research. Within the scope of the study, normality tests were performed to determine whether the data were suitable for the normal distribution.

In cases where the sample size is less than 50, the Shapiro-Wilk test is used to decide on normality, and in cases where it is greater than 50, the Kolmogorov-Smirnov test is used (Büyüköztürk, 2023). For this reason, Shapiro-Wilk test was preferred for the analysis of the data within the scope of the study (N=29).

The interpretation of the p value in the normality test is that the data are normally distributed when it is greater than .05, and the data deviates from normal when it is less than .05 (Büyüköztürk, 2023). The fact that the skewness and kurtosis values are in the range of -1.96 to +1.96 shows that the data are normally distributed (Can, 2024).

In the analysis process of the data obtained from the BYT, the answers given by each pre-service teacher were primarily recorded as raw data. In addition, it was determined how many people repeated the answers given by the pre-service teachers, and original and creative responses were identified and analysed. Then, the BYT was evaluated according to the determined fluency, flexibility and originality scoring criteria. While scoring the answers to the questions, the harmony between the answers given by the researcher and an expert in the field independently of each other was examined. The scoring criteria for BYT questions are given in Table 3.6.

Table 3.6: BYT scoring criteria

Items	Scoring Criteria
Question 1,2,3,4	1 point for each response generated (fluency score) +1 point for each different recommended application (flexibility score) 2 points for each response found in less than 5% of people, 1 point for 5% to 10% (originality score)
Question 5	3 points for each response found in less than 5% of respondents, 2 points for each response found in 5% to 10%, 1 point for each response found in more than 10% of respondents (originality).

Question 6	For each response, evaluation is made in three dimensions: tool, method and application. Students of all sizes are assessed on 3 points (flexibility). 3 points for each response found in less than 5% of respondents, 2 points for responses between 5% and 10%, 1 point for more than 10% responses (authenticity)
Question 7	3 points of flexibility for each function of the machine. It also has an authenticity score between 1 and 5 based on a comprehensive overall impression

While calculating the scoring reliability among the researchers, Miles and Huberman's (1994) formula Reliability = Consensus/ (Consensus + Disagreement) x 100 was used. For a reliable analysis, this value must exceed at least the 80% limit. As a result of the calculation, the percentage of agreement in the data analysis between the two researchers was determined as 89.6%. This ratio shows that the reliability of data analysis in the research is high. The responses that could not reach a consensus between the two researchers were analysed by a science education expert as the third researcher. In this way, the analysis was completed by achieving full consensuses for all responses.

Shapiro-Wilk normality test was applied to determine whether the data obtained from the BYT showed normal distribution. The test results were examined to assess whether they met the assumption of normality. The obtained data are presented in Table 3.7.

Table 3.7: BYT Shapiro-Wilk normality test results

		N	Statistics	p	Skew	kurtosis
BYT	Pre-test	29	.953	.225	.762	.365
	Post-test	29	.844	.001	1.657	3.382

According to Table 3.7, when the results of the Shapiro-Wilk pretest are examined, the p value is .225 and it is not suitable for the normal distribution (p>0.05), and when the results of the Shapiro-Wilk post-test are examined, the p value is .001 (p<0.05). In addition, the skewness (.762) and kurtosis (.365) values in the pre-test results show a normal distribution because they are between -1.96 and +1.96, and the skewness (1.657) and kurtosis (3.382) values in the post-test results are above 1.96. For this reason, Wilcoxon Signed Ranks Test was used to evaluate the differences between parameters.

Shapiro-Wilk normality test was applied to determine whether BSCT data showed normal distribution. The test results were examined to assess whether they met the assumption of normality. The obtained data are presented in Table 3.8.

Table 3.8: BSBT Shapiro-Wilk normality test results

		N	Statistics	P	Skew	kurtosis
BSBT	Pre-test	29	.887	.005	-.911	.724
	Post-test	29	.860	.001	-1.162	.800

According to Table 3.8, when the Shapiro-Wilk pre-test-post-test results are examined, the data are not normally distributed because the p value is less than .05 (p<.05). In addition, the skewness and kurtosis values in the pre-test-post-test results are between -1.96 and +1.96, so they show a normal distribution. However, since the p-value is not suitable for normal distribution, Wilcoxon Signed Ranks Test was used to evaluate the differences between parameters.

Shapiro-Wilk normality test was applied to determine whether the data of the Multidimensional 21st Century Skills Scale showed normal distribution. The test results were examined to assess whether they met the assumption of normality. The obtained data are presented in Table 3.9.

Table 3.9: Results of the Shapiro-Wilk normality test of the MPLS

		N	Statistics	p	Skew	kurtosis
MPS	Pre-test	29	.941	.107	.711	.428
	Post-test	29	.917	.025	1.098	1.138

According to Table 3.9, when the results of the Shapiro-Wilk pre-test are examined, the p value is .107 and it is not suitable for the normal distribution because the p value is .107 ($p>0.05$), and when the results of the Shapiro-Wilk post-test are examined, the p value is .025 ($p<0.05$). In addition, the skewness and kurtosis values in the pre-test and post-test results are between -1.96 and +1.96, so they show normal distribution. However, since the p-value was less than .05 in the post-test results, the Wilcoxon Signed Ranks Test was used to evaluate the differences between parameters.

3.5. Data Collection Process

In this study, the data collection process was carried out in the Fall semester of the 2024-2025 academic year, and the participants consisted of students of Balıkesir University Necatibey Faculty of Education, Department of Science Education. Before the data used in the research were collected, the necessary permissions were obtained from the Balıkesir University Science and Engineering Sciences Ethics Committee and then the data collection process was started.

The research was carried out in the form of pre-test and post-test. At the beginning of the process, pre-test was applied to the teacher candidates. Then, pre-service teachers were provided with the opportunity to prepare and present STEM-based lesson plans for 10 weeks. After this process was completed, the final test was applied. The data collection process was carried out in a laboratory environment and participation in the research was voluntary. In addition, at the beginning of the research, the purpose of the study was explained to the pre-service teachers, and it was stated that they were expected to give sincere and sincere answers to the questions.

The STEM lesson plans prepared by the teacher candidates have been prepared in line with the subjects in the secondary school science curriculum. Topics were selected from the science curriculum at the 5th, 6th, 7th and 8th grade levels of secondary school. 29 pre-service teachers prepared lesson plans within the framework of STEM subjects by dividing into groups of two or three, and presentations lasting 60 minutes were made in each group in two groups per week. A sample lesson plan template was provided to guide pre-service teachers in the process of preparing a lesson plan. In the template, the name of the activity, subject, duration, grade level, key concepts, security measures and learning outcomes for the relevant STEM disciplines are specified. The course consists of introduction (probing preliminary information, arousing curiosity, attracting attention), application (identifying the problem, developing possible solutions, finding the most appropriate solution, making and testing the prototype) and communication (evaluation) stages. Thanks to this structure, it is aimed for pre-service teachers to experience problem solving, creative and critical thinking skills by using the engineering design process. The researcher and the advisor faculty member examined the lesson plans before the application, then followed the application process and made observations, and at the end of the application, they gave feedback to the teacher candidates. The visual of the pre-service teachers on constant speed movement at the 7th week is presented in Figure 3.1, the visual on friction at the 8th week is presented in Figure 3.2, and the visual about voice at the 11th week is presented in Figure 3.3.

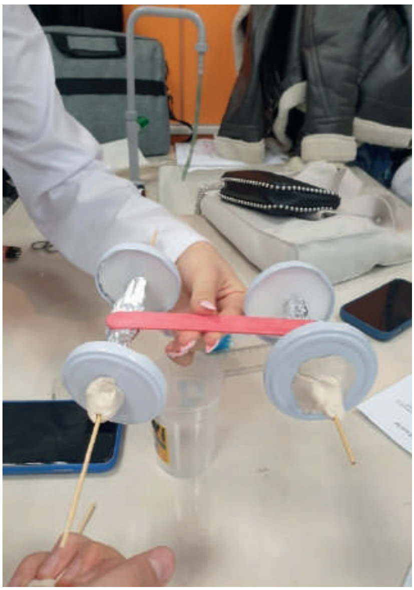

Figure 3.1: Image of the topic of constant velocity motion in week 7

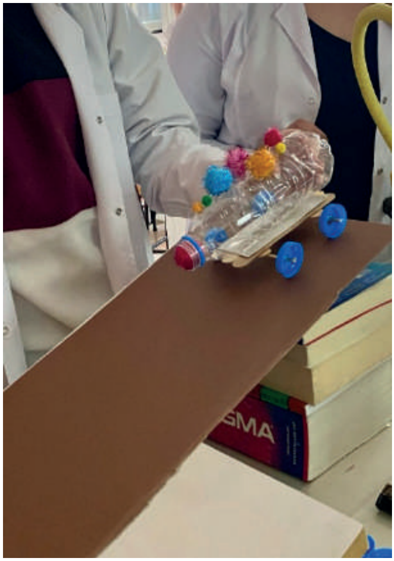

Figure 3.2: Image of the topic of friction in week 8

Figure 3.3: Image of the Week 11 audio topic

One of the lesson plans prepared in accordance with the STEM approach within the scope of the study is the activity titled "Temperature Design Journey". This activity was held with the aim of "Developing a creative thermos design that minimizes heat loss by experimentally observing the heating rates of liquids and the effects of mass on temperature rise." The activity is planned in accordance with the 8^{th} grade Science course outcomes. In this way, pre-service teachers were allowed to develop interdisciplinary skills.

The event process was carried out as follows:

In the activity, pre-service teachers were asked to design a thermos by considering the factors affecting its capacity to retain heat. In this direction, pre-service teachers examined the materials from which the thermos should be made, how its shape should be, which materials insulate heat better, and the effects of design on heat conservation.

First, the insulation materials were presented to the pre-service teachers and the pre-service teachers reasoned which materials to choose. Then, pre-service teachers were expected to develop their own thermos models based on these materials. Teacher candidates made digital drawings of the products they designed from the Tincercad application, which is a three-dimensional modelling program within the scope of technology discipline. In the engineering discipline, pre-service teachers have developed a thermos design that can keep hot drinks hot for a long time using scientific data. In the discipline of mathematics, they analysed and interpreted the data obtained from the experiments and made measurements about the size of the thermos.

In the experimental part of the activity, pre-service teachers were presented with containers containing three different liquids: 250 ml of water, 250 ml of olive oil, 500 ml of water. Pre-service teachers observed the temperature change in these containers at 0, 3, and 5 minutes and examined the effects of liquid type and amount on temperature change.

During the event, students effectively used 21st century skills such as critical thinking, problem solving, reasoning, creativity, reasoning, and engineering design. Within the scope of the activity, sample thermos designs prepared about Matter and Heat and Temperature in the 10th week are presented in Figure 3.4.

Figure 3.4: Sample thermos designs prepared on the topic of Matter and Heat, Temperature in the 10th week

Within the scope of the study, one of the lesson plans prepared in accordance with the STEM approach is "Mirror Football: To the Castle with Strategy!" is the event titled. In the activity, it was aimed for pre-service teachers to understand the reflection properties of light and to develop their problem-solving skills by applying this information creatively. The activity is planned in accordance with the 6th grade Science course outcomes. In the activity, pre-service teachers were expected to deliver the light source (soccer ball) from the starting point to the goal using mirrors. They were asked to design a strategic roadmap from flat, hollow and bump mirrors to change the direction of the light.

Within the scope of the activity, pre-service teachers were divided into four groups and given instructions. Pre-service teachers were asked to follow these instructions and produce solutions to the problem situation in cooperation. Each group made a design on a cardboard surface designed in the form of a football field, using the reflection properties of the mirrors to reach the goal with the laser light they placed inside the soccer ball. Each group is assigned the task of using at least one bump, pit and flat mirror, and changing the direction of the laser light at least three times.

In the technology part of the event, pre-service teachers were asked to create animations from the Algodoo application to digitize their designs. In the engineering dimension, pre-service teachers created their designs using their engineering design skills. In the discipline of mathematics, pre-service teachers made ratio-proportion calculations in the designs they created, and used measurement, drawing and analysis skills. Thus, a learning environment has been created in which all disciplines of STEM are integrated. Within the scope of the event, sample football field designs prepared about Optics in the 11th week are presented in Figure 3.5.

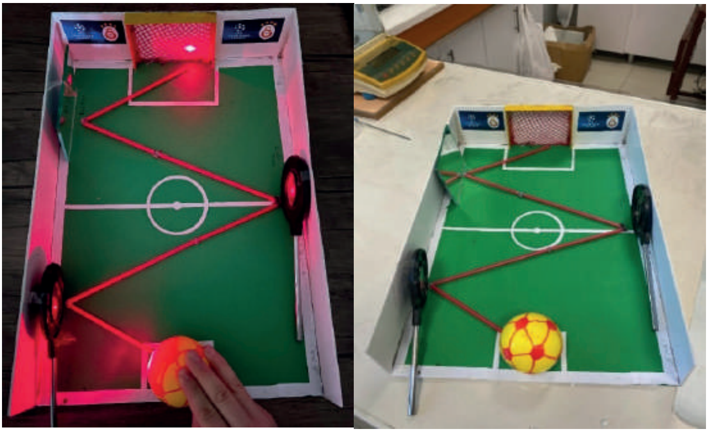

Figure 3.5: Sample football field designs prepared on the topic of Optics in Week 11

4. Findings

In the study, the effect of the STEM approach on scientific creativity, scientific process skills and 21st century skills of 3rd grade science teacher candidates within the scope of Science Teaching Laboratory Applications I course were examined. In this section, the findings obtained from the analysis of the data obtained from the Scientific Creativity Test (BYT), Scientific Process Skills Test (BSBT), Multidimensional 21st Century Scale (MPYS) of pre-service teachers are mentioned.

Findings on the first sub-problem:

Does STEM education make a significant difference in the scientific creativity levels of 3rd grade science teacher candidates between pre-test and post-test scores before and after the application? To seek an answer to the sub-problem, normality analyses of the data obtained from BYT were performed and Wilcoxon Signed Ranks Test was used to evaluate the differences between parameters due to the deviation from normal. The findings are given in Table 4.1.

Table 4.1: Findings from the BYT Wilcoxon signed ranks test

Post-Test- Pre-test	N	Rank Average	Sum of Ranks	Z	P
Negative Ranks	11	11.00	121.00	-1.868	.062
Positive Ranks	17	16.76	285.00		
Equal Rows	1				
Sum	29				

According to Table 4.1, there was no statistically significant difference between the pre-test and post-test scores as a result of the Wilcoxon signed ranks test (Z= -1.868, p= .062). This finding shows that STEM-based laboratory applications do not provide a significant change in the scientific creativity scores of science teacher candidates.

The distribution of pre-test and post-test scores for BYT was examined descriptively to reveal the implementation process in general terms. The findings are given in Table 4.2.

Table 4.2: Findings from the descriptive analysis of the BYT

Test Type	Mean	Standard Deviation (SD)
Pre-Test	38.69	10.43
Final Test	45.49	16.49

According to Table 4.2, the results of the descriptive analysis indicate the differences between the pre-test and the post-test. The mean score of the pretest was 38.69 (SD=10.43) and the mean score of the post-test was 45.49 (SD= 16.49). This result shows that the post-test average is 6.8 points higher than the pre-test. Although pre-service science teachers scored higher in the post-test than in the pre-test, there was no significant difference between the pre-test and post-test average scores.

Findings on the second sub-problem:

Does STEM education make a significant difference in the scientific process skills between the pre-test and post-test scores of 3rd grade science teacher candidates before and after the application? To search for an answer to the sub-problem, normality analyses of the data obtained from BSBT were performed and Wilcoxon Signed Ranks Test was used to evaluate the differences between parameters due to the deviation from normal. The findings are presented in Table 4.3.

Table 4.3: Findings from the analysis of the BSBT Wilcoxon signed ranks test

Post-Test- Pre-test	N	Rank Average	Sum of Ranks	Z	P
Negative Ranks	13	14.62	190.00	-.024	.981
Positive Ranks	14	13.43	188.00		
Equal Rows	2				
Sum	29				

In Table 4.3, the Wilcoxon Signed Ranks Test was applied to determine whether there was a statistically significant difference between the pre-test and post-test scores. As a result of the test, Z= -0.024, p=.981 was found to be and there was no statistically significant difference between the pre-test and post-test scores because the p value was greater than .05. This finding shows that STEM-based laboratory applications do not provide a significant change in the scientific process skills scores of science teacher candidates.

The distribution of pre-test and post-test scores for BSBT was examined descriptively to reveal the implementation process in general terms. The data are given in Table 4.4.

Table 4.4: Findings from BSBT descriptive analysis

Test Type	Mean	Standard Deviation (SD)
Pre-Test	21.45	3.04
Final Test	21.79	4.09

According to Table 4.4, the results of the descriptive analysis indicate the differences between the pre-test and the post-test. The mean score of the pre-test was 21.45 (SD=3.04) and the mean score of the post-test was 21.79 (SD= 4.09). This result indicates that the post-test average is 0.34 points higher than the pre-test. However, when the overall scores are examined, it seems that there is no significant difference between the pre-test and post-test scores of science teacher candidates.

Findings on the third sub-problem:

Does STEM education make a significant difference in 21st century skills (critical thinking, problem solving, creative thinking, etc.) between the pre-test and post-test scores of 3rd grade science teacher candidates before and after the application? To search for an answer to the sub-problem, the normality analysis of the data obtained from the MPS was performed and the Wilcoxon Signed Ranks Test was used to evaluate the differences between the parameters due to the deviation from the normal. The findings are presented in Table 4.5.

Table 4.5: Findings from the Wilcoxon Signed Ranks Test

Post-Test- Pre-test	N	Rank Average	Sum of Ranks	Z	p
Negative Ranks	13	13.69	178.00	-.264	.791
Positive Ranks	14	14.29	200.00		
Equal Rows	2				
Sum	29				

In Table 4.5, the Wilcoxon Signed Ranks Test was applied to determine whether there was a statistically significant difference between the pre-test and post-test scores. As a result of the test, Z= -0.264, p=.791 and it was determined that there was no statistically significant difference between the pre-test and post-test scores because the p value was greater than .05. This finding shows that STEM-based laboratory applications do not provide a significant change in the 21st century skills scores of science teacher candidates.

The distribution of pre-test and post-test scores for the MPLS was examined descriptively to reveal the implementation process in general terms. The findings are given in Table 4.6.

Table 4.6: Findings from the descriptive analysis of the MPLS

Test Type	Mean	Standard Deviation (SD)
Pre-Test	161.24	16.35
Final Test	161.69	14.77

According to Table 4.6, the results of the descriptive analysis indicate the differences between the pre-test and the post-test. The mean score of the pre-test was 161.24 (SD=16.35) and the mean score of the post-test was 161.69

(SD= 14.77). This result shows that the post-test average is 0.45 points higher than the pre-test. However, when the overall scores were examined, it was determined that there was no significant difference between the pre-test and post-test scores of the science teacher candidates.

The Friedman test was applied to determine whether there was a significant difference between the results of three different measurements in the comparison of the measurements for scientific creativity, scientific process skills and 21st century skills. The findings of the relevant tests are given in Table 4.7.

Table 4.7: Findings from the Friedman test on differences in scales

STEM Activities	N	Rank Average	SD	χ^2	P	Significant Difference
Scientific Creativity Pre-Test	29	3.31	5	130.922	.000	Meaningful
Scientific Creativity Final Test	29	3.60				
Scientific Process Skills Pre-Test	29	1.52				
Scientific Process Skills Final Test	29	1.57				
21st Century Skills Pre-Test	29	5.48				
21st Century Skills Final Test	29	5.52				

Looking at the findings obtained from the Friedman test in Table 4.7, there is a significant difference in Scientific Creativity, Scientific Process Skills and 21st Century Skills of STEM-based laboratory applications (χ2= 130.922, p<.001). Post-hoc analyses are required to determine between which variables this difference occurs.

The findings obtained from the pre-test post-hoc analyses, which examined the differences in Scientific Creativity, Scientific Process and 21st Century Skills, are given in Table 4.8.

Table 4.8: Findings from the pre-test post hoc analysis on the differences of the scales

Comparison		N	Rank Average	Sum of Ranks	Z	P
21st Century Skills - Scientific Creativity	Negative Ranks	0	.00	.00	-4.704	.000
	Positive Ranks	29	15.00	435.00		
	Equal Rows	0				
	Sum	29				
Scientific Process Skills - Scientific Creativity	Negative Ranks	28	15.48	433.50	-4.673	.000
	Positive Ranks	1	1.50	1.50		
	Equal Rows	0				
	Sum	29				
Scientific Process Skills - 21st Century Skills	Negative Ranks	29	15.00	435.00	-4.705	.000
	Positive Ranks	0	.00	.00		
	Equal Rows	0				
	Sum	29				

Table 4.8 presents the findings obtained from the Wilcoxon Signed-Rank Test to determine which groups had significant differences after the Friedman test. When the findings were examined, it was concluded that the p value was .000 in all comparisons and these differences were statistically

significant (p<.05). When the Bonferroni correction was made, the p-value of each comparison remained the same. This shows that the test is still meaningful.

The findings obtained from the post-test post-hoc analyses, which examined the differences in Scientific Creativity, Scientific Process and 21st Century Skills, are given in Table 4.9.

Table 4.9: Findings from post-test post hoc analysis of differences in scales

Comparison		N	Rank Average	Sum of Ranks	Z	p
21st Century Skills - Scientific Creativity	Negative Ranks	0	.00	.00	-4.707	.000
	Positive Ranks	29	15.00	435.00		
	Equal Rows	0				
	Sum	29				
Scientific Process Skills - Scientific Creativity	Negative Ranks	29	15.00	435.00	-4.705	.000
	Positive Ranks	0	.00	.00		
	Equal Rows	0				
	Sum	29				
Scientific Process Skills - 21st Century Skills	Negative Ranks	29	15.00	435.00	-4.704	.000
	Positive Ranks	0	.00	.00		
	Equal Rows	0				
	Sum	29				

When Table 4.9 was examined, it was determined that the p value was .000 in all comparisons and these differences were statistically significant (p<.05). When the Bonferroni correction was made, the p-value of each comparison remained the same. In this case, it seems that the test is still meaningful.

5. Discussion, Conclusion and Recommendations

In this section, the results obtained within the scope of the study were discussed and the results were compared with the studies in the literature. In addition, suggestions were made for researchers who will work on this subject.

5.1. Discussion and Conclusion

Within the scope of this study, the effects of STEM-based laboratory applications on scientific creativity, scientific process skills and 21st century skills of 3rd grade science teacher candidates were examined and the results obtained were discussed.

5.1.1. Discussion on the effect of STEM education on the scientific creativity levels of 3rd grade science teacher candidates

When the results of the BYT applied within the scope of the study were examined, there was no significant difference between the pre-test and post-test scores. However, when the results of the descriptive analysis were examined, it was seen that the post-test scores increased compared to the pre-test scores. Although this situation does not reveal a significant difference, it shows that STEM applications contribute to the creative thinking skills of teacher candidates. At the same time, it is seen that the standard deviation has increased in the descriptive analysis results. This indicates that the development of pre-service teachers is at different levels. In other words, it shows that the tests are not equally effective in every teacher candidate.

When the literature was examined, studies similar to the results obtained in this study were found. In his study, Çelik Keser (2021) examined the effect of STEM education on the scientific creativity of pre-service science teachers. As a result of the study, there was no significant difference in the scientific creativity skills of the pre-service teachers. In their study, Şahin Pekmez, Aktamış and Can (2010) concluded that there was no significant change between the creativity steps of pre-service teachers. However, there are many studies in the literature showing that STEM education positively affects scientific creativity. Doğan and Kahraman (2021) concluded that STEM activities have a positive effect on students' scientific creativity in their study examining the effect of STEM practices on secondary school students' scientific creativity. In their study, Üret and Ceylan (2021) stated that STEM applications positively affect the creativity of 5-year-old children and that this effect is permanent. In their study, Özkaya, Bulut and Şahin (2022) concluded that STEM applications increase creativity skills. Güldemir and Çınar (2021) mentioned the positive effect of STEM activities on developing creativity skills in their studies. Similarly, Conradty and Bogner (2020), Hanif, Wijaya and Winarno (2019), Hebebci and Usta (2022), Sarıca (2024) and Şentürk Özkaya (2022) stated that the STEM approach positively affects scientific creativity.

When the results obtained from this study and other studies are examined, it is seen that some factors play a decisive role in the inability of STEM education to make a significant difference on scientific creativity. These are among the factors that make it difficult to implement STEM effectively, where the application time may not be sufficient, the number of participants may be limited, the prior knowledge of the participants may be insufficient, the environmental conditions are not suitable, and the problems experienced in the supply of materials. In the study published by Eroğlu and Bektaş in 2016, they examined the views of science teachers on the STEM approach. They stated that science teachers wanted to apply STEM but could not practice it because they had problems in terms of time and materials. In their study published in 2015, Bagiati and Evangelou stated that preschool teachers who teach with STEM applications have problems with time. In their study, Taktat Ateş et al. (2022) stated the limitations faced by academics in applying STEM. These limitations are as follows: The limited duration of the course and the intensive curriculum that needs to be completed. In the study published by Köse and Ataş in 2020, it was observed that teachers had problems in terms of lack of materials and time while implementing STEM education. In their 2016 study of teachers in South Korea, Park, Byun, Sim, Han and Baek found that teachers faced various difficulties while implementing STEM lessons. These difficulties are as follows: Limited duration of class hours, STEM courses require effort in terms of planning and implementation, they do not receive the necessary support from the school administration, lack of material.

5.1.2. Discussion on the effect of STEM education on the scientific process skills levels of 3rd grade science teacher candidates

When the results obtained from the BSCT applied in the study are examined, it is seen that there is no significant difference between the pre-test and post-test scores. When the results of the descriptive analysis were examined, it was seen that the post-test scores increased slightly compared to the pre-test scores. Even if this situation does not reveal a significant difference, it shows that STEM applications contribute to the scientific thinking skills of teacher candidates, albeit a little. At the same time, the fact that the standard deviation of the posttest is greater than the pre-test indicates that there is more diversity among pre-service teachers in the post-test. However, he also states that this result leaves the ideas of the pre-service teachers largely the same.

In the literature, there are existing studies that are parallel to the results obtained from the research. In the studies of Bahşi and Açıkgül Fırat (2020), although the scientific process skills of 8th grade students of STEM applications improved within themselves in the experimental group, no significant difference was observed when compared to this development control group. However, these results contradict other studies in the literature. Taştan Akdağ and Güneş (2021) determined in their study that STEM activities have a positive effect on the development of scientific process skills. In the study published by Köngül and Yıldırım (2021), it was seen that the STEM approach made a significant difference on the scientific process skills and STEM achievements of 6th grade students. Gürsoy, Bebek and Bülbül (2023) stated that the STEM approach has a positive effect on scientific process skills because of their meta-analysis of graduate theses examining the effect of the STEM approach on scientific process skills since 2017. Likewise, Gökbayrak and Karışan (2017), Abanoz and Deniz (2019), Özkul and Özden (2020) concluded that STEM has positive effects on SPS in their studies.

When the results of this study are examined, it is thought that sample size, lack of materials, readiness, motivation and participation levels of pre-service teachers may be effective as the reason why pre-service teachers do not show a significant change in scientific process skills. In their study, Atalay and Armağan (2023) stated that factors such as insufficient readiness levels of students and lack of materials negatively affect the STEM education process. In his study published in 2018, Yıldırım stated the problems faced by teachers while implementing STEM education. These problems seem to be the physical environment, the number of students, the inappropriateness of the curriculum, the noise of the students in group work and the lack of time. In their study, Çınar and Terzi (2021) determined that teachers encounter problems such as lack of materials, time problems, and noise during STEM teaching. In the study they published in 2022, Meral and Altun Yalçın stated that STEM-based teachers have problems in terms of time adjustment, classroom management difficulties, lack of materials, infrastructure problems and lack of workforce.

5.1.3. Discussion on the impact of STEM education on 21st century skills levels of 3rd grade science teacher candidates

When the results of the multidimensional 21st century skills test applied in the study were examined, there was no significant difference between the pre-test and post-test scores. However, when the results of the descriptive analysis are examined, it is seen that the post-test scores increase very slightly compared to the pre-test scores. Although the test did not show a significant difference, it shows that STEM applications contribute very little to the 21st century skills of pre-service teachers. At the same time, the fact that the standard deviation of the post-test is smaller than the pre-test indicates that pre-service teachers show more similar results in the post-test. However, since the difference is very small, it seems that the ideas of the pre-service teachers mostly remain the same.

When the literature was examined, studies with similar results were found. As a result of the study in which Sarıbaş (2023) examined the contribution of STEM education to the development of 21st century skills, it was found that the scores of students' 21st century skills (communication, critical thinking, etc.) increased, but this increase was not statistically significant. At the same time, it was stated that the increase in these skills was higher than in the control group. However, there are many studies in the foreground that STEM activities improve 21st century skills. In his study, Hacıoğlu (2021) gave STEM activities training to science teacher candidates for 14 weeks and as a result, it was found that STEM activities improve 21st century skills. Stehle and Burton (2019) examined the effect of teachers in STEM high schools on the development of 21st century skills by examining the lesson plans of STEM high schools, and because of the study, it was found that STEM high schools support 21st century skills. However, it has been observed that teachers have deficiencies in providing students with these skills. Similarly, Bircan and Çalışıcı (2022), Çalışkan and Şenler Pehlivan (2024), Fajrina, Lufri and Ahda (2020) concluded that STEM applications improve 21st century skills in their studies.

There may be more than one possible reason why 21st century skills in the study did not show a significant difference between pre-test and post-test scores. 21st century skills (critical thinking, creative thinking, problem solving, etc.) may take a long time to develop. The development of these skills should be observed over time. Because development is likely to be seen in the longer term. At the same time, it is thought that the reason for the lack of development of 21st century skills may be due to factors such as sample size, time constraint, lack of materials, motivation and readiness of teacher candidates. In his study conducted in 2023, Akan stated that the lack of physical environment, time problems and financial inadequacies negatively affected teachers' practices of STEM education. In their study, Hiğde, Aktamış, Yazıcı, Özen Ünal, Arabacıoğlu, Şen and Dalgıç (2022) emphasized that teachers should have sufficient knowledge about other disciplines because STEM is an interdisciplinary approach. For this reason, it is thought that the inadequacy of the readiness of the teacher candidates for other disciplines affects the result of the study. In their studies on STEM education with pre-service teachers, Bozkurt Altan, Yamak and Buluş Kırıkkaya (2016) worked in groups with pre-service teachers. In these studies, they stated that having a computer in each group slowed down the process, so the pre-service teachers had time problems. Güleç Çiftçi and Şentürk (2024) stated in their study that teachers have problems in implementing STEM education due to factors such as the technical infrastructure of the school and lack of materials.

5.1.4. Discussion of multiple benchmark results for STEM-based laboratory applications

Within the scope of the study, multiple comparisons were made to examine the change in the level of scientific creativity, scientific process skills and 21st century skills of pre-service teachers in more detail and to compare the individual development differences in these skill areas. A significant difference was observed between pre-test and post-test scores in all three scales. These results show that STEM-based laboratory practices differ significantly from each other in pre-service teachers' scientific creativity, scientific process skills and 21st century skills. This result shows that STEM-based laboratory applications do not provide an equal level of impact on every skill but create a more consistent or strong interaction on some skills. In the study, when the results of descriptive analysis are examined, it is seen that the biggest increase is in scientific creativity skills. However, when the results of the Friedman test were examined, the most improvement in terms of developmental consistency among pre-service teachers was realized in 21st century skills. This situation suggests that it may be since some pre-service teachers are highly developed in scientific creativity and some pre-service teachers are less developed. In other words, it shows that the development is not similar for all pre-service teachers.

Post hoc analyses were performed to determine which tests caused this significant difference. As a result of the pairwise comparisons made between the pre-test and post-test data, significant differences were observed in all pairings ("scientific creativity - scientific process skills", "scientific creativity - 21st century skills", "scientific process skills - 21st century skills"). Bonferroni corrections have been made to minimize the risk of error in Post Hoc analyses that can be caused by multiple comparisons. As a result, statistical significance continued. This situation reveals that pre-service teachers show different levels of development in all three skill areas. It is noteworthy that there is a significant difference between the scales in the pre-test scores obtained in post hoc analysis. Before the application, it was expected that there would be no significant difference, but the difference shows that the pre-service teachers initially differed from each other in terms of some skills. The reason for this situation may be due to the different level of readiness and interest of teacher candidates. The fact that there was a significant difference between the scales in the scores obtained from the post-hoc analyses after the post-test may have had a stronger effect on some skills than others. These differences provide information about the quality of the skills developed by the pre-service teachers throughout the process. Considering that 21st century skills mostly cover processes such as problem solving and cooperation, it shows that these skills are one of the areas most affected by practice. Because these skills are built on more solid foundations over time.

These results show that STEM-based laboratory practices have a significant and holistic effect on pre-service teachers' scientific creativity, scientific process skills and 21st century skills. The significance obtained because of post hoc analyses shows that STEM activities do not only appeal to the group but also support individual development. As a result, it has been concluded that STEM-based laboratory applications are effective in developing different skills of science teacher candidates. The fact that the interventions do not have the same level of effect on every skill shows that some skills are more open to development. The high increase in points in scientific creativity indicates that the development of these skills is rapid and pronounced. This result indicates that there is a high jump in some pre-service teachers. In other words, it does not show a consistent development. Although there is less increase in scores in 21st century skills, scores may be more consistent and widely distributed across pre-service teachers. This does not indicate individual jumps, but consistent change within the group. Scientific creativity is a field in which pre-service teachers can directly demonstrate their imagination and ability to generate original ideas. When appropriate learning conditions are provided, it can develop in a short time. 21st century skills evolve over time by transforming into behaviour. For this reason, its development is slower. This shows that the development rates of different skills are at different levels.

The study was carried out only with pre-service teachers studying in a specific department at a university. This situation restricts the diversity of the sample. The low sample size negatively affects the generalizability of the results obtained. At the same time, there is a possibility that the technology literacy levels of the teacher candidates are insufficient, which has negatively affected the implementation process. In addition, the inadequacy of the readiness levels of the teacher candidates, the deficiencies in the physical infrastructure of the school (lack of materials, etc.), and the lack of interest of some teacher candidates in STEM education can be listed as the difficulties encountered in the study. It is thought that longer-term implementation of STEM education may have different results.

Similarly, in the study published by Özbilen in 2018, he stated that teachers who want to apply STEM suffer from lack of materials. In his study, Yılmaz (2019) found that students had difficulty in using the discipline of technology in STEM activities. In their study, Tarkın Çelikkıran and Aydın Günbatar (2017) found that pre-service teachers had difficulty in deciding how to design the product and which materials to use during STEM design. It is thought that these difficulties are because pre-service teachers have not had such an experience before. At the same time, they also stated that pre-service teachers had time constraints in the process.

5.2. Suggestions

Based on the results of this research, the following suggestions can be made for future studies:

For science teacher candidates to develop scientific creativity, scientific process skills and 21st century skills, STEM-based applications should be given more space throughout undergraduate education. These practices will broaden the perspectives of pre-service teachers and support their creative thinking, critical thinking and problem-solving skills.

To provide more meaningful and concrete developments in the scientific creativity, scientific process skills and 21st century skills of teacher candidates, studies should be planned in a long-term and systematic manner. In the process, it is important that the person conducting the study is guiding and encouraging at the point of guidance to be given to teacher candidates.

STEM education should be product+process-oriented, not just product-oriented. Being product-oriented alone is insufficient to develop students' creative thinking and problem-solving skills. Being process-oriented will support the student's ability to make sense of the problem-solving steps and think critically. In this way, the development processes of the students can be examined at every stage.

Course content related to STEM education should be increased in teacher education programs and the content of these courses should be updated to support scientific creativity, scientific process skills, 21st century skills and other skills.

In future studies, STEM applications should be in a way that appeals to different grade levels. In this way, the effect of STEM applications on all age groups can be examined.

In future studies, the effects of integrating different learning approaches with STEM applications on developing students' different skills and enriching their learning experiences can be examined.

It is recommended that future studies should be planned for a longer term, a larger sample group should be reached by increasing the participant base, and more in-depth analyses should be made by diversifying data collection tools (interviews, etc.).

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