Bartın University Journal of Faculty of Education
BUEFAD Volume 14, Issue 3
813-828
dergipark.org.tr/buefad
DOI: 10.14686/buefad.1649805

# The Effect of STEM Applications on Mathematics Achievement: A Meta-Analysis Study

***Samet Gündüz a & Neşe Dokumacı Sütçü b****

a PhD student, Institute of Educational Sciences, Dicle University, Diyarbakır, Turkey, https://orcid.org/0000-0003-2458-5384

b Associate Professor, Department of Mathematics and Science Education, Ziya Gökalp Faculty of Education, Dicle University, Diyarbakır, Turkey, https://orcid.org/0000-0003-3279-4194 *ndokumaci@dicle.edu.tr

**Research Article**
Received: 3.3.2025
Revised: 29.6.2025
Accepted: 16.7.2025

## Abstract

This study aims to determine the effect of STEM applications on mathematics achievement using the meta-analysis method. For this purpose, postgraduate theses in Türkiye were analysed. As a result of the review, 25 postgraduate theses related to the topic were initially identified, and data from 14 theses that met the inclusion criteria were included in the meta-analysis. Data analyses were carried out using the Comprehensive Meta-Analysis statistical program. While applying the meta-analysis method, homogeneity test was performed by calculating the effect sizes of the studies. Since the studies showed a heterogeneous structure as a result of the homogeneity test, the random effects model was used to calculate the overall effect size. Hedges's g coefficient was used to determine the effect sizes. Funnel plot and Rosenthal's safe N statistic were used to examine publication bias. The classification of Thalheimer and Cook (2002) was used to interpret the effect sizes obtained as a result of the analyses. In the study, it was determined that the effect sizes of all studies included in the meta-analysis were positive. Only two of the studies had a small effect, while the other studies showed at least a medium effect. The overall effect size value for mathematics achievement was found to be 0.901. Based on these results, it can be said that STEM activities have a positive and large effect on increasing mathematics achievement.

**Keywords:** STEM, mathematics, meta-analysis, academic achievement

# STEM Uygulamalarının Matematik Başarısına Etkisi: Bir Meta-Analiz Çalışması

## Öz

Bu araştırmada STEM uygulamalarının matematik başarına etkisini meta-analiz yöntemiyle belirlemek amaçlanmıştır. Bu amaçla Türkiye'de yapılmış lisansüstü tezler incelenmiştir. Yapılan inceleme sonucunda ilk aşamada konu ile ilgili 25 lisansüstü tez belirlenmiş olup bu çalışmalardan dâhil edilme kriterlerine uygun olan 14 lisansüstü teze ait veriler meta-analiz kapsamına dâhil edilmiştir. Veri analizleri Comprehensive Meta-Analysis istatistik programı ile gerçekleştirilmiştir. Meta-analiz yöntemi uygulanırken çalışmalara ait etki büyüklükleri hesaplanarak homojenlik testi yapılmıştır. Homojenlik testi sonucunda çalışmalar heterojen bir yapı gösterdiğinden dolayı genel etki büyüklüğü hesaplanırken rastgele etkiler modeli kullanılmıştır. Etki büyüklüklerinin belirlenmesi için Hedges's g katsayısı kullanılmıştır. Yayın yanlılığının incelenmesinde ise huni grafiği ve Rosenthal'ın güvenli N istatistiğinden yararlanılmıştır. Yapılan analizler neticesinde elde edilen etki büyüklüklerinin yorumlanmasında Thalheimer ve Cook'un (2002) yaptığı sınıflandırma kullanılmıştır. Araştırmada, meta-analiz kapsamına alınan tüm çalışmaların etki büyüklüklerinin pozitif yönde olduğu tespit edilmiştir. Çalışmalardan sadece ikisi küçük düzeyde etkiye sahipken, diğer çalışmalar en az orta düzeyde etki göstermiştir. Matematik başarısına yönelik genel etki büyüklüğü değeri 0.901 olarak bulunmuştur. Bu sonuçlardan hareketle STEM etkinliklerinin matematik başarısını artırmada olumlu yönde ve geniş düzeyde bir etki gösterdiği söylenebilir.

**Anahtar Sözcükler:** STEM, matematik, meta-analiz, akademik başarı

To cite this article in APA Style:

Gündüz, S., & Dokumacı Sütçü, N. (2025). The effect of STEM applications on mathematics achievement: A meta-analysis study. *Bartın University Journal of Faculty of Education, 14*(3), 813-828. https://doi.org/10.14686/buefad.1649805

# INTRODUCTION

Today, science and technology are rapidly advancing. It is crucial for countries to adapt to these changes and innovations in science and technology. It can be said that the most important way to achieve this adaptation is through education. As a result of these innovations and changes, individuals are expected to develop various knowledge and skills such as communication, problem-solving, critical thinking, and creativity, as well as to grow in a multidimensional manner (Ministry of National Education [MoNE], 2024a). Therefore, different teaching models are needed to meet these expectations. In order to adapt to innovations and changes and to ensure that students acquire and develop these skills, countries are diversifying their education systems and making changes to their curricula. In Türkiye, new curricula based on the Türkiye Century Education Model (TCEM) were announced in 2024 and have been gradually implemented starting from the 2024-2025 academic year. The fundamental changes in education have primarily focused on four key disciplines—science, technology, engineering, and mathematics—aiming to integrate these disciplines with one another (Genç, 2023). The TCEM core text (MoNE, 2024a) also emphasizes the importance of interdisciplinary connections in the programs designed to equip students with essential competencies. It highlights that interdisciplinary relations play a significant role in moving beyond discipline-focused knowledge transfer, providing students with a holistic perspective, and ensuring lasting learning experiences. In this context, TCEM aims not only to deepen students' knowledge and skills in a specific discipline but also to develop their ability to establish interdisciplinary connections. Within this framework, the STEM approach stands out as an interdisciplinary model.

The word STEM is formed by combining the initials of the disciplines science, technology, engineering, and mathematics. STEM was first defined as an educational terim by Judith A. Ramaley in 2001, who stated that the concept of science is broad and encompasses many different fields (Yıldırım & Altun, 2015). There are various definitions of STEM in the literature. Lueangsuwan and Srikoon (2021) define STEM as an interdisciplinary field that integrates the four fundamental principles of science, technology, engineering, and mathematics, using active and holistic approaches based on real-world problems. Similarly, Tezel and Yaman (2017) describe STEM as an interdisciplinary educational approach that aims to help students develop skills such as teamwork, communication, creative thinking, problem-solving in daily life, inquiry, and research by integrating the knowledge and skills from these four disciplines. Another definition of STEM emphasizes increasing the number of qualified professionals in STEM-related careers and addressing problems from a holistic perspective by supporting theoretical knowledge in science and mathematics with engineering applications to develop technological products (Bybee, 2011). As can be seen from these definitions, although there are multiple explanations in the literature, they all share the common point that STEM is an interdisciplinary approach centered around science, technology, engineering, and mathematics. However, while STEM brings together these four disciplines, it is more than just a combination of them; it is an approach that ensures effective and high-quality learning, applies existing knowledge in daily life, and encompasses economic, military, and higher-order thinking dimensions (Yıldırım & Altun, 2015). Although STEM is fundamentally about bringing real-life problems into educational settings, real-world problems are not so simple that they can be reduced to a single discipline; rather, they are complex. Therefore, solving such problems requires the integration of multiple disciplines (Bakan, 2024).

STEM applications vary from country to country. STEM education first emerged in the United States in the 1980s as part of an educational reform movement, integrating science, mathematics, and technology into K-12 education. Later, engineering was incorporated, and the integration of these four disciplines led to the adoption of the STEM approach as it is known today (Wells, 2016). South Korea, however, took a different approach from the United States by adding the discipline of art to the four fields included in STEM education, thus creating STEAM. This approach aims to foster the creation of more creative and original products (Çiftçi, 2018). Today, many countries around the world, including the United States, South Korea, Austria, Germany, Brazil, Finland, the United Kingdom, and China, place significant importance on STEM education. In Türkiye, until 2015, the Ministry of National Education had not prepared a strategic action plan for STEM education. The first step was taken in 2014 when the Turkish Industry and Business Association (TUSIAD) published a report. This report emphasized the critical role of STEM fields in economic and technological development, highlighting the importance of an interdisciplinary approach in the education system and the need to increase the number of qualified professionals (TUSIAD, 2014). Subsequently, a STEM Education Report was prepared in 2016 and it was recommended that the report be taken into consideration and used as a resource in the process of updating existing education programmes (MoNE, 2016). In light of these developments, starting in 2017, science, mathematics, and technology design curricula were revised within the framework of STEM education. Additionally, various materials such as activity-based websites, activity books, and guidebooks were developed to support teachers in implementing

STEM-based instruction in their classrooms (Çınar & Terzi, 2021). Most recently, the 2024 TCEM curriculum has allocated significant space to interdisciplinary approaches and STEM. The Middle School Mathematics Curriculum emphasizes interdisciplinary connections by highlighting contexts and problems in which mathematics is used, particularly in science. For example, it states that scientific activities such as research, inquiry, experimentation, and observation should be addressed through an interdisciplinary and context-based approach (MoNE, 2024b). In the High School Mathematics Curriculum, the necessity of incorporating more STEM applications has been explicitly stated. For instance, in the topic of derivatives, an example is given where the growth rate of a bacterial population at a specific time t can be determined by modeling the population with functions (MoNE, 2024c).

STEM education represents a transformation from teaching science and mathematics as separate subjects to a multidisciplinary, integrated education model (Riechert & Post, 2010). The STEM approach aims to incorporate real-life problems into the educational process and develop applicable solutions for these problems (Akgündüz, 2018). Real-life problems cannot be considered independently of mathematics; on the contrary, mathematics is an inseparable part of these problems and serves as the foundation of the solution process. Moore et al. (2013) stated that for students to have meaningful learning experiences in mathematics and science, technology should be used effectively, and they should be actively involved in engineering design processes. Understanding the effects of STEM applications in mathematics education is crucial for establishing more effective interdisciplinary connections and enhancing students' ability to solve real-world problems. STEM education allows students to develop critical thinking skills, which are essential for success in mathematics. It enables them to analyze complex problems, generate innovative solutions, and strengthen their ability to think outside the box (Eshaq, 2024). From this perspective, the STEM approach, which emphasizes interdisciplinary relationships, is expected to introduce a new perspective to mathematics education and lay the groundwork for effective mathematics teaching (Sümen, 2018).

In the world, numerous studies are being conducted on STEM applications. In particular, discussions on how STEM applications affect mathematics achievement have attracted great interest from researchers and educators. These studies generally indicate that the STEM approach positively impacts students' mathematics achievement by helping them develop skills such as problem-solving, critical thinking, and creativity. However, the differences in findings across these studies make it difficult to reach a general conclusion. For example, some studies (Cengiz, 2024; Eshaq, 2024; Macun, 2019; Özdemir, 2018; Türk, 2023; Zhang & Skaalvik, 2021) suggest that the STEM approach significantly improves mathematics achievement, while others (Bicer & Capraro, 2019; Gülbahar, 2023; Hyacinth, 2019; Karadeniz, 2019) report a more limited effect. Additionally, a review of the literature reveals a significant increase in the number of articles and graduate theses related to STEM applications in recent years. Along with this increase, systematic reviews and analysis studies on STEM have also begun to emerge. It has been observed that most STEM-related studies in the literature are concentrated in the field of science, while research on its other components—technology, engineering, and mathematics—is more limited. Studies examining research trends in STEM (Çalışkan & Okuşluk, 2021; Herdem & Ünal, 2018) have also determined that most studies focus on the field of science. Furthermore, Kwak and Ryu (2016) noted that STEM research in Korea has also progressed with a science-centered approach. As a result, while there are numerous meta-analysis studies on STEM in the field of science in Türkiye (Ademoğlu, Emre & Akyürek, 2024; Arshad, Halim & Nasri, 2020; Boz, 2023; Gümüş & Eroğlu, 2024; Değerli & Yapıcı, 2022; Mao et al., 2021), no meta-analysis study has been found specifically in the field of mathematics. Therefore, this study aims to analyze the effects of STEM applications on students' mathematics achievement by synthesizing statistical data from published graduate theses using the meta-analysis method to obtain an overall effect size. By compiling data from various studies, this research seeks to provide a more comprehensive understanding of the general trends in STEM's impact on mathematics achievement and to fill gaps in the literature. Determining the role of STEM applications in mathematics achievement in education can help educators and policymakers develop effective teaching strategies.

## METHOD

### Research Design

In this study, the meta-analysis method was used. Meta-analysis is a quantitative method that combines the results of two or more studies to obtain a general conclusion (Şen & Yıldırım, 2020). Since this study aims to combine research findings on the effects of STEM applications on students' mathematics achievement to reach an overall conclusion, this method was deemed appropriate.

### Data Collection

In this study, conducted to determine the effects of STEM applications on students' mathematics achievement using the meta-analysis method, graduate theses conducted in Türkiye were examined. To access the studies to be included in the meta-analysis, the National Thesis Center of the Council of Higher Education was searched. The keywords "STEM," "STEAM," and "FETEMM" were used during the search. Since the history of graduate theses on STEM applications is not very long, no time filter was applied. To access the most recent graduate theses, the search process was repeated at regular intervals. The final search was conducted on October 31, 2024, marking the end of the data collection process.

As a result of the screening process, the identified graduate theses were examined, and in the first stage, qualitative studies and studies that did not investigate the effect on academic achievement were eliminated. After this elimination process, a pool of 25 graduate theses that examined the impact on academic achievement was created. To determine which theses would be included in the meta-analysis from this pool, the following criteria were considered:

- The study design must be an experimental design with a pre-test and post-test control group.
- Parametric tests must have been used in the studies.
- The thesis must include the necessary statistical data (standard deviation, arithmetic mean, sample size) required to calculate the effect size.

In the second stage, the graduate theses in the study pool were re-examined in detail based on the criteria mentioned above. Eight of these postgraduate theses were excluded from the meta-analysis because they did not conform to the pre-test-post-test control group experimental design, one because they did not use parametric tests, and two because they did not include the statistical data necessary to calculate the effect size. As a result of the review, 11 graduate theses that were not suitable for meta-analysis were excluded from the study, and 14 graduate theses were included in the meta-analysis. Descriptive data related to the conducted literature review are presented in Table 1.

**Table 1.** Descriptive Data on the Conducted Literature Review

| | Reached Graduate Theses | Included Graduate Theses | Excluded Graduate Theses | Percentage of Included Theses |
|---|---|---|---|---|
| Master's Thesis | 21 (%84) | 12 (%86) | 9 (%81,8) | %57 |
| Doctoral Thesis | 4 (%16) | 2 (%14) | 2 (%18,2) | %50 |
| Total | 25 (%100) | 14 (%100) | 11 (%100) | %56 |

When Table 1 is examined, it is seen that 56% of the graduate theses in the study pool met the inclusion criteria and were included in the meta-analysis. The majority of these theses included in the meta-analysis (86%) consist of master's theses.

### Data Coding

A coding form consisting of two sections was developed to include all the necessary data from the graduate theses included in the meta-analysis. In the first section of the coding form, descriptive data such as the publication year and type of thesis are recorded. The second section contains statistical data required for calculating meta-analytic effect sizes, including the arithmetic mean, standard deviation, and sample size. To ensure the reliability of the coding process, two researchers conducted the coding independently, and no discrepancies were found between their results. Microsoft Excel was used to transfer the data recorded in the coding form into an electronic format. The method for transferring the statistical data recorded in the coding form into an electronic environment is detailed in Figure 1.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | No | Study | Year | Type | Geographical Region of Data Collection | Implementation Duration | Sample Size | Sample Group | Pre-test | | | | | | Post-test | | | | | |
| 2 | | | | | | | | | Experimental group | | | Control group | | | Experimental group | | | Control group | | |
| 3 | | | | | | | | | Arithmetic mean | Standard deviation | Sample size | Arithmetic mean | Standard deviation | Sample size | Arithmetic mean | Standard deviation | Sample size | Arithmetic mean | Standard deviation | Sample size |
| 4 | 1 | Atay | 2024 | YL | Marmara | 3 Hafta | 40 < x < 80 | İlköğretim | 11,23 | 3,63 | 30 | 10,02 | 3,57 | 30 | 12,63 | 4,63 | 30 | 10,33 | 4,00 | 30 |
| 5 | 2 | Aydın | 2022 | YL | Marmara | 3 Hafta | x ≤ 40 | İlköğretim | 3,75 | 1,61 | 16 | 3,19 | 1,52 | 16 | 12,56 | 1,90 | 16 | 9,19 | 1,22 | 16 |
| 6 | 3 | Cengiz | 2024 | YL | Ege | 8 Hafta | 40 < x < 80 | İlköğretim | 77,63 | 9,91 | 19 | 73,70 | 12,54 | 23 | 86,05 | 7,74 | 19 | 72,39 | 10,96 | 23 |

**Figure 1.** *The method of transferring statistical data into an electronic format*

As seen in Figure 1, the studies are coded in a format where each row contains a sequential number, the author's last name, and the data for a single graduate thesis. For example, the row with sequence number 1 contains data from the master's thesis published in 2024 by the author with the last name "Atay". The section where statistical data is coded is divided into two parts: pre-test and post-test data. Each section is further divided into two groups: experimental and control groups. Then, the statistical data for each group is entered into the appropriate cells. For instance, in the row numbered 2, the pre-test arithmetic mean for the experimental group in the study coded as "Aydın" is entered in cell I5 as "3.75".

**Data Analysis**

The effectiveness of the process was analyzed using the meta-analysis method. In this process, effect sizes for each study were calculated, and a homogeneity test was conducted. Since the homogeneity test revealed that the studies exhibited a heterogeneous structure, the random-effects model was used to calculate the overall effect size. Comprehensive Meta-Analysis (CMA) software was used for conducting the meta-analytic analyses. The significance level was set at 0.05. While calculating effect sizes, the CMA software interface that allows input of the standard deviation, sample size, and arithmetic mean for the experimental and control groups was selected. Effect sizes were calculated using Hedges's g coefficient. To examine publication bias, a funnel plot and Rosenthal's fail-safe N statistic were utilized. In interpreting the obtained effect sizes, the classification by Thalheimer and Cook (2002) was used due to its broader scale. The data related to this classification are presented in Table 2.

**Table 2.** Thalheimer and Cook's (2002) Effect Size Classification

| Threshold | Classification |
|---|---|
| Effect size< 0.15 | Insignificant |
| 0.15 ≤ Effect size< 0.40 | Small |
| 0.40 ≤ Effect size< 0.75 | Medium |
| 0.75 ≤ Effect size< 1.10 | Large |
| 1.10 ≤ Effect size< 1.45 | Very Large |
| 1.45 ≤ Effect size | Excellent |

**Research Ethics**

In this study, postgraduate theses conducted in Türkiye were examined to determine the effect of STEM applications on students' mathematics achievement using the meta-analysis method. Since the study is based on the secondary analysis of existing data, it does not require ethics committee approval.

## FINDINGS

In this section of the study, the findings obtained from the analyses and the interpretations related to these findings are presented. The findings are examined in two parts. The first part includes findings related to the descriptive data of the studies included in the research, while the second part presents findings related to the meta-analytic data.

**Findings on Descriptive Data**

Figure 2, displays the distribution of publication years for the graduate theses included in the meta-analysis.

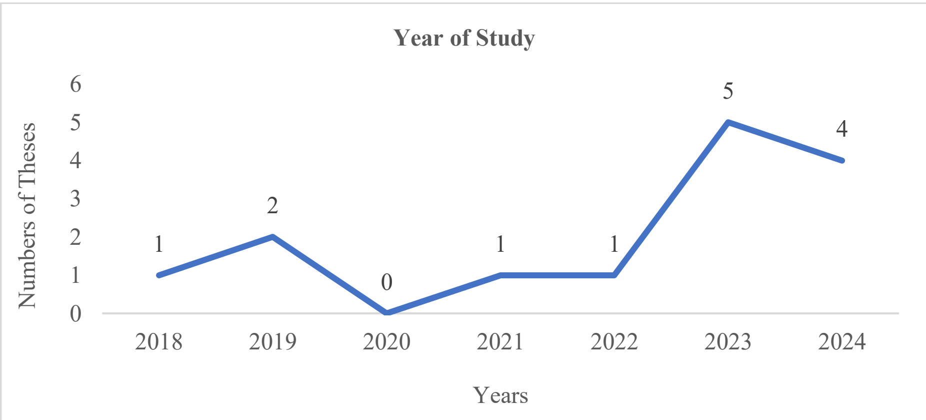

**Figure 2.** *Distribution of publication years for the graduate theses included in the meta-analysis.*

As seen in Figure 2, the oldest thesis included in the meta-analysis dates back to 2018, and more than half of the theses were conducted in the last two years. No studies from the year 2020 were found. Figure 3 presents the geographical distribution of data collection regions in the graduate theses included in the meta-analysis.

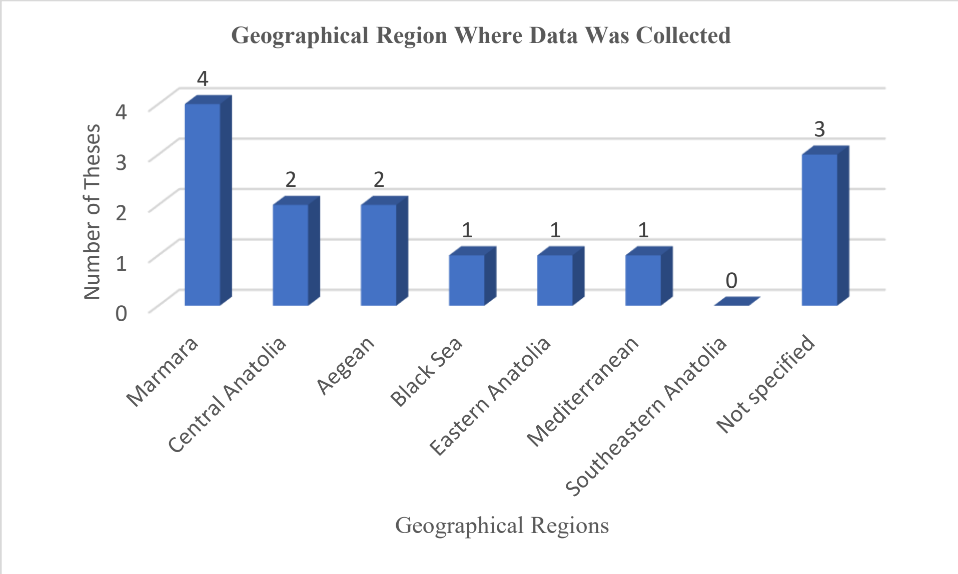


**Figure 3.** *Geographical distribution of data collection regions in graduate theses included in the meta-analysis*

As shown in Figure 3, the majority of the data in the theses were collected from the Marmara region. Overall, the distribution across regions can be considered heterogeneous. It was determined that no graduate thesis included data collected from the Southeastern Anatolia region. In three of the theses, the specific province or region from which the data were collected was not specified. The distribution of the sample groups in the graduate theses included in the meta-analysis is presented in Figure 4.

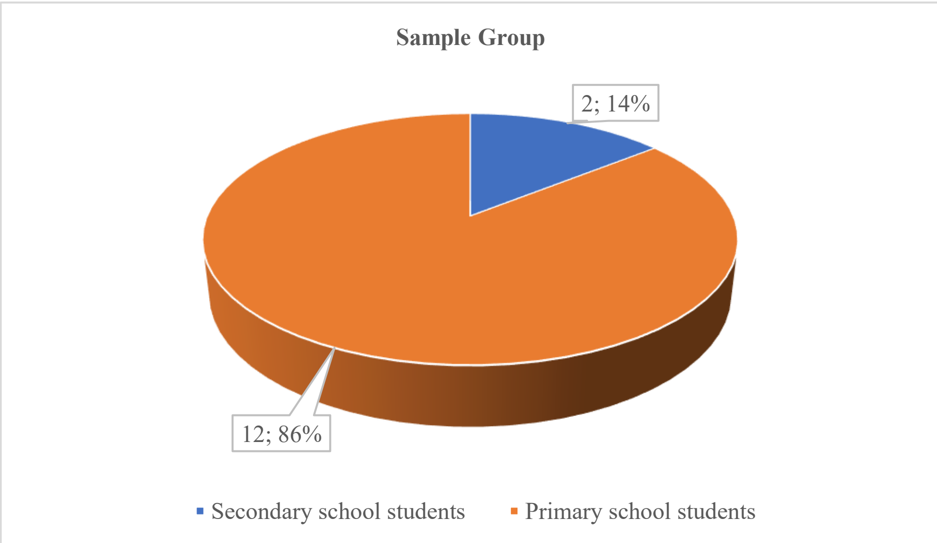


**Figure 4.** *Distribution of sample groups in graduate theses included in the meta-analysis*

According to Figure 4, the sample group in all the graduate theses consisted of students. The majority of these students were primary school students. The number of theses conducted with secondary school students was quite limited. No graduate thesis was found that studied student groups outside primary and secondary education (such as preschool or higher education). The distribution of sample sizes in the graduate theses included in the meta-analysis is presented in Figure 5.

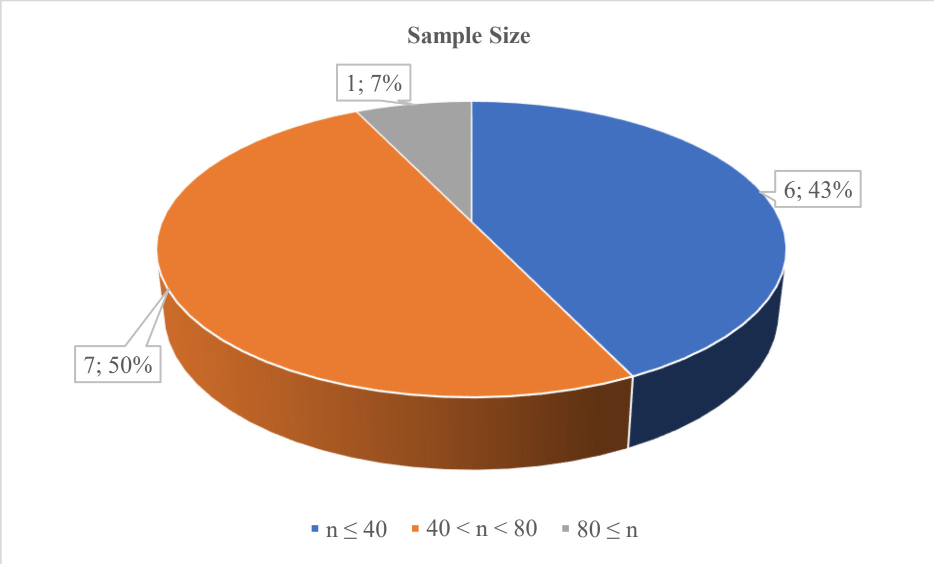


**Figure 5.** *Distribution of sample sizes in graduate theses included in the meta-analysis*

The sample of the 14 studies included in the meta-analysis consisted of a total of 686 students, with 353 in the control group and 333 in the experimental group. When examining Figure 5, it is observed that in half of the theses, a sample size of between 40 and 80 students, which can be considered medium-sized, was preferred. Only one study was conducted with a sample group consisting of 80 or more students. Figure 6 presents the distribution of the postgraduate theses included in the meta-analysis according to their implementation duration.

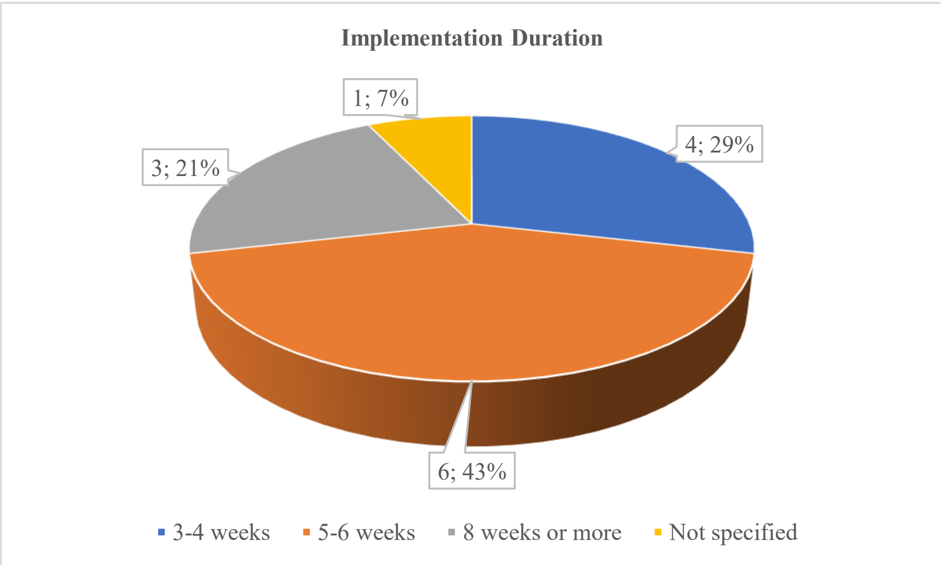


**Figure 6.** *Distribution of the postgraduate theses included in the meta-analysis based on implementation duration*

As seen in Figure 6, the most common experimental application duration in the postgraduate theses included in the meta-analysis was 5-6 weeks, followed by 3-4 weeks. There were three theses in which the experimental application lasted 8 weeks or longer, while one postgraduate thesis did not specify the application duration.

**Findings on Meta-Analytical Data**

Before calculating effect sizes, the postgraduate theses included in the meta-analysis were examined for publication bias. For this purpose, a funnel plot of the studies included in the research was analyzed and is presented in Figure 7.

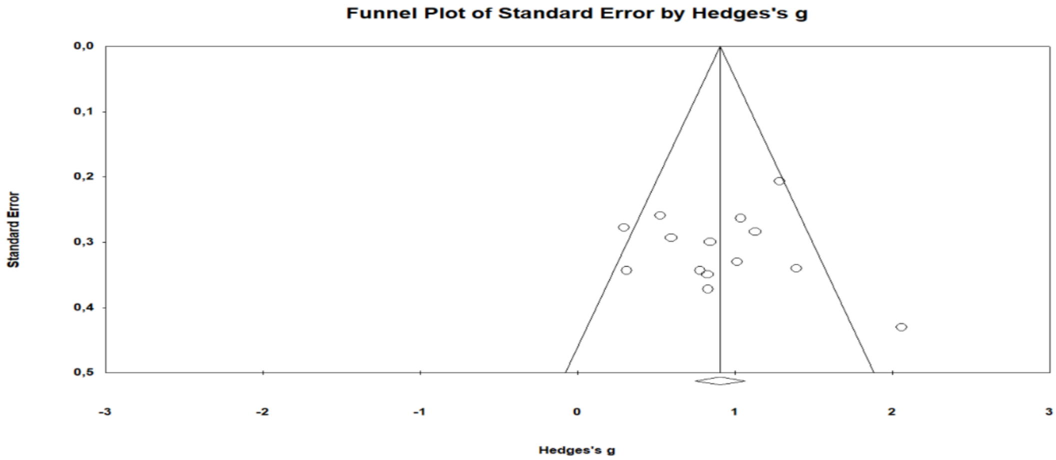


**Figure 7.** *Funnel plot of effect sizes in the postgraduate theses included in the meta-analysis*

The most commonly used method to detect publication bias is the examination of a funnel plot. In a funnel plot, all individual studies are expected to be located within the inner region of the funnel and symmetrically distributed around the central line, which represents the overall effect. If most individual studies are positioned outside the funnel or if their effect sizes are asymmetrically distributed around the central effect line, this may indicate the presence of publication bias (Dinçer, 2014). When examining the funnel plot in Figure 7, it is observed that nearly all effect sizes are within the inner region of the funnel and generally exhibit a distribution close to symmetry around the central line. Based on this, it can be concluded that there is no publication bias in the study. To further confirm the absence of publication bias, statistical analyses related to publication bias were also conducted. The results of these analyses are presented in Table 3.

**Table 3.** Publication Bias Statistics of the Studies

| Bias Status | Value |
|---|---|
| Z-value for observed studies | 11.15304 |
| p-value for observed studies | 0.00000 |
| Alpha | 0.05 |
| Direction | 2 |
| Z-value for Alpha | 1.95996 |
| Number of observed studies | 14 |
| Safe N | 440 |

In the study, publication bias was checked using Rosenthal's safe N statistic. As shown in Table 3, the safe N was found to be 440. The safe N represents the number of studies with an effect size of zero that would be required for the overall effect size to become statistically insignificant (Dinçer, 2014). In other words, for the p-value to exceed the alpha value, an additional 440 studies would need to be included in the analysis. Since this number is quite high, it can be concluded that publication bias in this study is low.

After examining the publication bias of the studies included in the meta-analysis, it is necessary to determine which statistical model will be used to calculate the overall effect size. When selecting the statistical model for calculating the overall effect size, the homogeneity or heterogeneity of the studies included in the meta-analysis should be examined. If the individual study results exhibit a homogeneous structure, the fixed-effects model should be used; if they exhibit a heterogeneous structure, the random-effects model should be applied (Dinçer, 2014). To determine whether the studies included in the meta-analysis are homogeneous or heterogeneous, the graphical representation of effect sizes was first examined. The distribution of effect sizes for individual studies is presented graphically in Figure 8.

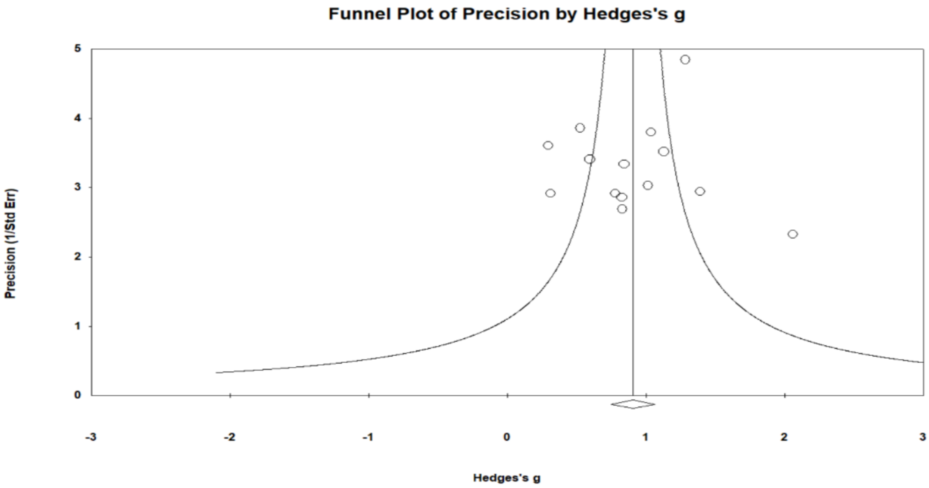


**Figure 8.** *Graphical representation of effect sizes in individual studies*

In Figure 8, the diamond represents the overall effect, while the circles indicate the effect sizes of individual studies. In the graphical representation of effect sizes, individual studies are expected to be positioned within the inner region of the trend lines. If most individual studies fall within the trend lines, the studies can be considered homogeneous; if they are positioned outside the trend lines, the studies may be interpreted as heterogeneous. Upon examining the graph, it is observed that studies are present both within and outside the trend lines. Therefore, to precisely determine whether the studies are homogeneous or heterogeneous, the p-value or Q-value should be considered (Dinçer, 2014). To make a definitive assessment of the heterogeneity status of the study, a homogeneity test was conducted. Table 4 presents the findings of the homogeneity test.

**Table 4.** Homogeneity Test Results

| Homogeneity Value (Q) | Degrees of Freedom (df) | $I^2$ | p |
|---|---|---|---|
| 24.954 | 13 | 47.904 | 0.023 |

As shown in Table 4, the homogeneity test resulted in a Q-value of 24.954. Upon examining the $\chi^2$ table, the critical value for 13 degrees of freedom at a 95% significance level was found to be 22.362. Since the Q-value (24.954) is greater than the critical value (22.362), it can be concluded that the studies included in the research exhibit a heterogeneous structure. Additionally, the p-value being less than 0.05 ($p = 0.023 < 0.05$) further supports the heterogeneity of the studies. Therefore, the random-effects model was used for calculating and interpreting the overall effect size. The results of the general effect size calculations based on the random-effects model for the postgraduate theses included in the meta-analysis are presented in Table 5.

**Table 5.** Overall Effect Size Values According to the Random-Effects Model

| Model | Overall Effect Size | 95% Confidence Interval | | Standard Error |
|---|---|---|---|---|
| | | Lower Bound | Upper Bound | |
| Random Effects | 0.901 | 0.679 | 1.122 | 0.113 |

According to the random-effects model, the overall effect size was determined to be 0.901 with a standard error of 0.113. The positive effect size indicates that the effect favors the experimental group in which STEM applications were implemented. Additionally, in the z-test conducted for statistical significance, the z-value for the random-effects model was calculated as 7.977. This z-value is statistically significant with p = 0.000. Since the p-value is smaller than the significance level of 0.05, it indicates a significant difference between the groups. Based on these findings, it can be concluded that STEM applications have a positive impact on improving students' mathematics achievement. According to the classification by Thalheimer and Cook (2002), this effect is considered to be at a broad level. The forest plot displaying the distribution of effect sizes for the studies included in the meta-analysis according to the random-effects model is presented in Figure 9.

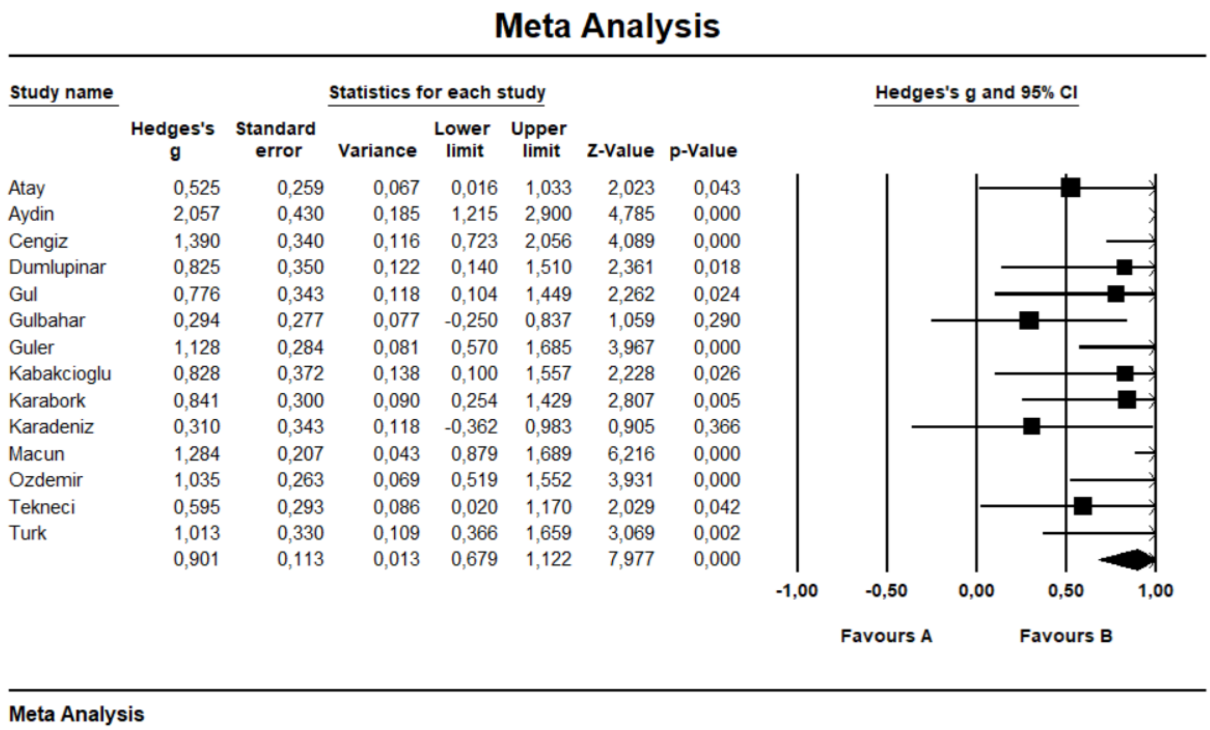


**Figure 9.** *Forest plot of effect sizes based on the random-effects model*

The forest plot in Figure 9 presents the effect sizes of the studies included in the meta-analysis. The studies are labeled using the authors' last names. The position of the black squares relative to the vertical line at 0.00 indicates the effect size of each study. The lines extending from the squares represent the lower and upper limits of the 95% confidence interval for each effect size. The diamond in the shape of a rhombus at the bottom of the forest plot shows the overall effect size of the studies according to the random effects model. When individual studies are examined, it is seen that the lowest effect size is 0.294 (Gülbahar, 2023) and the highest effect size is 2.057 (Aydın, 2022). In addition, there is no study with a negative effect size among the studies included in the meta-analysis. The positive direction of all effect sizes indicates that STEM applications consistently favor the experimental group. The distribution of individual studies based on their effect size levels is presented in Table 6.

**Table 6.** Distribution of Studies by Effect Size Levels

| Effect Size Level | Frequency (f) | Percentage (%) |
|---|---|---|
| Insignificant | 0 | 0.0 |
| Small | 2 | 14.3 |
| Medium | 2 | 14.3 |
| Large | 6 | 42.9 |
| Very Large | 3 | 21.4 |
| Excellent | 1 | 7.1 |

Table 6 presents the classification of the studies included in the meta-analysis based on their effect size levels. Nearly half of the studies (f = 6, 42.9%) were found to have a large effect. No studies were classified as having an insignificant effect. Only two of the studies included in the meta-analysis had a small effect size, while the remaining studies exhibited at least a medium effect.

## DISCUSSION & CONCLUSION

The STEM approach is an interdisciplinary field that integrates the four fundamental principles of science, technology, engineering, and mathematics, utilizing active and holistic approaches based on real-world problems (Lueangsuwan & Srikoon, 2021). It aims to incorporate real-life problems into the educational process and develop applicable solutions for these problems (Akgündüz, 2018). In addition to being a globally recognized approach integrated into education systems, it has also become an important and popular research area for scholars in recent years (Gülhan, 2022). Indeed, when examining the distribution of the graduate theses included in this study over the years, it is evident that the majority have been published in recent years. Similarly, Mandev and Yavuz (2022), in their content analysis of research on STEM, stated that a significant number of studies have been conducted in Türkiye especially in recent years, and that the number of graduate theses and articles has been steadily increasing. They also found that most of the studies they analyzed were conducted within the last five years. Based on this information, it can be said that the number of graduate theses related to STEM has increased over the years. This trend indicates the growing importance of the STEM approach and the increasing interest of researchers in this field. Likewise, recent educational policies aimed at promoting innovation have traditionally focused on increasing participation in the disciplines of science, technology, engineering, and mathematics (OECD, 2016). While the majority of the graduate theses included in this study are at the master's level, the number of doctoral dissertations is more limited. Similar findings were reported by Çavaş, Ayar, and Gürcan (2020), Demir (2022), and Gülhan (2022), who analyzed trends in STEM research in Türkiye and found that master's theses outnumber doctoral dissertations at a comparable rate. This may be due to the wider availability of master's programs. Additionally, STEM fields may be more attractive at the master's level for young academics, as this stage allows students to explore new research areas and complete their studies in a relatively short time. The graduate theses included in this research were predominantly conducted in the Marmara region. Similarly, Kalemkuş (2020) found that the highest number of experimental studies on STEM were conducted in Istanbul, located in the Marmara region. Considering Turkey's population distribution, where the Marmara region has a higher population density than other regions, this finding is expected. Most of the studies were conducted with primary school (elementary and middle school) students. Content analysis studies on STEM (Çalışkan & Okuşluk, 2022; Çavaş, Ayar & Gürcan, 2020; Ecevit, Yıldız & Balcı, 2022; Gülhan, 2022; Günbatar & Tabar, 2019; Kalemkuş, 2020) also found similar results, indicating that middle school students were the most frequently studied group. Furthermore, Anderson (2021), in a systematic review of STEAM education studies, found that middle school students were the primary focus of STEAM research in the United States. Similarly, Christensen et al. (2015) suggested that middle school years are the most suitable period for implementing STEM education initiatives and programs. The studies included in this research mainly involved sample groups of 40 to 80 students, which can be considered a moderate sample size, and the implementations typically lasted between three and six weeks. Mandev and Yavuz (2022) found that most studies involved 31 to 100 participants, while Ecevit, Yıldız, and Balcı (2022), as well as Demir (2022), reported that studies most commonly included sample sizes of 0 to 50 participants. The duration of the interventions also aligns with findings in the literature. Gülhan (2022) reported that applied research studies usually lasted between five and nine weeks, with five weeks being the most common duration. Tümkaya and Ulum (2020) systematically analyzed approaches that enhance mathematics achievement and found that interventions typically lasted one to five weeks. Similarly, Günbatar and Tatar (2019) found that applied research studies generally lasted one to two months (four to eight weeks), while Kalemkuş (2020) identified that experimental research implementations typically spanned six to ten weeks. In conclusion, based on these similar findings, it can be stated that STEM research in Türkiye has been rapidly increasing, most studies have been conducted with primary school students, interventions typically last around five to six weeks, and researchers generally work with moderately sized sample groups.

In this study, the effect sizes of 14 graduate theses that conducted experimental research on the impact of STEM applications on students' mathematics achievement were calculated and combined using the meta-analysis method. It was observed that all combined effect sizes related to academic achievement were positive. The positive direction of the effect sizes indicates that STEM applications have a favorable impact on students' mathematics achievement in favor of the experimental group. In general, it is expected that studies with positive effect sizes outnumber those with negative effect sizes. Because studies generally use designs aimed at testing an effective method in education, the likelihood of these methods yielding positive results may be higher. Additionally, studies involving innovative and successful interventions tend to attract more attention, making them more likely to be published. Based on the random effects model, the meta-analysis of the included graduate theses revealed that the overall effect size was at a large level. Based on this finding, it can be concluded that STEM applications are highly effective in improving students' mathematics achievement. This is because STEM applications connect abstract mathematical concepts to real-world problems, making them more concrete. Through project-based and experiential learning methods, students actively engage in problem-solving and exploration, which enhances their mathematical thinking skills. Additionally, STEM activities provide an engaging, interactive, and motivating learning environment, strengthening collaborative learning and critical thinking skills. These factors are key reasons why STEM applications have a positive impact on mathematics achievement.

Although not directly related to mathematics, there are meta-analysis studies in the literature on STEM applications. In one of these studies, Gümüş and Eroğlu (2024) examined the impact of STEM applications in science education on academic achievement and found that the overall effect size was at a very large level. Similarly, Boz (2023) investigated the effect of STEM education on students' science achievement and determined that the overall effect size was at a large level, similar to the findings of this study. Likewise, Ademoğlu, Emre, and Akyürek (2021) concluded that the overall effect size of STEM applications on students' academic achievement, compared to traditional methods, was also at a large level. Yücelyiğit and Toker (2021) found that STEM applications in early childhood education had a moderate effect size. Looking at international studies, Thomas and Larwin (2023) conducted a meta-analysis at the middle school level and determined that STEM education had a moderate effect. Similarly, in another study by Wang et al. (2022), the impact of digital games on learning in different STEM subjects was examined, and a moderate effect size was found. Lueangsuwan and Srikoon (2021) also found that the STEM approach had a moderate impact on students' learning achievement in Thailand. On the other hand, Rahmatika et al. (2024) determined that the STEM approach had a large effect on physics learning. As seen, different studies have yielded different levels of effect sizes. These differences are thought to stem from variations in factors such as the sample group, sample size, discipline area, duration of the experiment, and the diversity of materials used. Despite these differences, the overall effect sizes are positive and at least moderate. However, while the effects of STEM applications on mathematics teaching appear to be positive and high, caution should be exercised when generalizing these results. This is because it is not entirely clear which aspects of the teaching processes contribute to this effect size. Therefore, conducting more in-depth contextual analyses, examining long-term effects, and evaluating the diversity of implementations are essential for ensuring the sustainability of this method in education.

STEM applications have been found to significantly enhance mathematics achievement at a high level. Based on this finding, it is recommended that teachers integrate this approach into their lessons and be encouraged to do so. This study is limited to graduate theses examining the impact of STEM applications on mathematics achievement in Türkiye. Future research could explore the effects of STEM applications on other variables such as attitude, motivation, and learning retention. In the literature, studies related to STEM are predominantly focused on science education, with most conducted at the middle school level. However, there is relatively less research on other STEM components, such as mathematics, technology, and engineering. In this context, more studies should be conducted in disciplines outside of science, particularly in regions where STEM applications are less prevalent, such as the Southeastern Anatolia Region. Additionally, expanding STEM applications across different educational levels and disciplines would provide a more comprehensive understanding of how its impact varies based on region, discipline, or grade level. All these recommendations will support the widespread adoption of STEM approaches in education. Moreover, the findings obtained from these studies will contribute significantly to educational policies and curriculum development.

## Limitations

- The study only includes postgraduate theses conducted in Türkiye; therefore, the findings cannot be generalized to the impact of STEM applications on mathematics achievement in other countries.
- Differences among studies (e.g., sample group, duration of implementation) may influence the results of the meta-analysis.

## Statements of Publication Ethics

In this study, the ethical principles of the publication process were rigorously followed, and the principles of integrity, transparency, and academic honesty were upheld in the research design, data collection, analysis, and reporting stages.

## Researchers’ Contribution Rate

| Authors | Literature review | Method | Data Collection | Data Analysis | Results | Conclusion | Review | Editing | Supervision |
|---|---|---|---|---|---|---|---|---|---|
| Author 1 | ☒ | ☒ | ☒ | ☒ | ☒ | ☒ | ☐ | ☐ | ☐ |
| Author 2 | ☐ | ☐ | ☐ | ☐ | ☐ | ☒ | ☒ | ☒ | ☒ |

## Conflict of Interest

The authors declare no conflict interests.

## REFERENCES

(* Sources marked with an asterisk were used for meta-analysis.)

Ademoğlu, E., Emre, F. B., & Akyürek, S. T. (2021). Effectiveness of STEM education on students' science course success: A Meta-analysis study. *Journal of Academic Social Science Studies*, *14*(88), 45-60.

Anderson, N. (2021). A systematic review of STEAM education research: Comparing American and Korean studies. *Academia Letters*, Article 1039. https://doi.org/10.20935/AL1039.

Akgündüz, D. (2018). *Okul öncesinden üniversiteye kuram ve uygulamada STEM eğitimi* (2. baskı) *[STEM education from pre-school to university in theory and practice (2nd edition)].* Anı publishing

Arshad, A. M., Halim, L., & Nasri, N. M. (2020). Impact of integrating science and engineering teaching approach on students' achievement: A meta-analysis. *Jurnal Pendidikan IPA Indonesia, 9*(2), 139–148. https://doi.org/10.15294/jpii.v9i2.29839

*Atay, Ü. (2024). *STEM etkinliklerinin 4. sınıf öğrencilerinin STEM tutumlarına ve matematik başarılarına etkisi [The impact of STEM activities on 4th grade students' STEM attitudes and mathematics achievements].* Master's thesis, Yıldız Teknik University.

*Aydın, T. (2022). *STEAM (STEM + SANAT) eğitiminde mandala etkinliklerinin 6. sınıf öğrencilerinin matematik başarısı ve yaratıcı düşünmelerine etkisi [The effects of mandala activities in STEAM (STEM + art) education on the mathematic achievement and creative thinking of 6th grade students].* Master's thesis, Dokuz Eylül University.

Bakan, G. (2024). *STEM etkinliklerinin ilkokul öğrencilerinin STEM tutumlarına, STEM kariyer ilgilerine ve 21. yüzyıl becerilerine etkisi [The effects of STEM activities on elementary school students' STEM attitudes, STEM career interests, and 21st century skills]*. Master's thesis, Cumhuriyet University.

Bicer, A., & Capraro, R. M. (2019). Mathematics achievement in the secondary high school context of STEM and non-STEM schools. *School Science and Mathematics, 119*(2), 61–71.

Boz, S. (2023). *STEM eğitiminin öğrencilerin fen başarısına etkisi: Bir meta-analiz çalışması [The effect of STEM education on students' science achievement: A meta-analysis study].* Master's thesis, Aksaray University.

Bybee, R. W. (2011). Scientific and engineering practices in K-12 classrooms. *Science Teacher, 78*(9), 34-4.

*Cengiz, B. (2024). *STEM kapsamında yapılan bir uygulamanın öğrencilerin matematik başarı düzeyleri ve tutumlarına etkisinin incelenmesi [Examining the effect of an application within the scope of STEM on students' mathematics achievement levels and attitudes].* Master's thesis, Marmara University.

Christensen, R., Knezek, G., & Tyler-Wood, T. (2015). Alignment of hands-on STEM engagement activities with positive STEM dispositions in secondary school students. *Journal of Science Education and Technology. 24*(6), 898–909.

Çalışkan, A., & Okuşluk, F. (2021). Türkiye'de STEM alanında ve eğitim-öğretim konusunda yapılmış olan lisansüstü tezlerin içerik analizi. [The content analysis of graduate thesis on education and in field STEM]. *Academia Journal of Educational Research*, *6*(1), 124-136.

Çavaş, P., Ayar, A., & Gürcan, G. (2020). Türkiye'de STEM eğitimi üzerine yapılan araştırmaların durumu üzerine bir çalışma [A study on the status of STEM education research in Turkey]. *YYU Journal of Education Faculty*, *17*(1), 823-854.

Çınar, S., & Terzi, S. Y. (2021). STEM eğitimi almış öğretmenlerin STEM öğretimi hakkındaki görüşleri. [Views of teachers taken STEM in-service training on STEM education]. *YYU Journal of Education Faculty*, *18*(2), 213-245.

Çiftçi, M. (2018). *Geliştirilen STEM etkinliklerinin ortaokul öğrencilerinin bilimsel yaratıcılık düzeylerine, STEM disiplinlerini anlamalarına ve STEM mesleklerini fark etmelerine etkisi [Effects of developed STEM activities on differential creative levels of students in middle school of students, differentials of STEM *disciplinary and differances of STEM professions STEM profession]*. Master's thesis, Recep Tayyip Erdoğan University.

Değerli, M., & Yapıcı, Ü. (2022). The effect of STEM approach in science education on academic success: A meta-analysis study. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education*, *16*(1), 17-48.

Demir, M. (2022). *Türkiye'de STEM ile ilgili yapılmış tez çalışmalarının eğilimleri [The tendencies of the theses on STEM which were done in Turkey].* Master's thesis, Aydın Adnan Menderes University.

Dinçer, S. (2014). *Applied meta-analysis in educational sciences*. Pegem Akademi Publishing.

*Dumlupınar, M. (2021). *FETEMM yaklaşımıyla işlenen 6. sınıf çarpanlar ve katlar konusunun öğrenci kazanımlarına etkisi [The effect of 6th grades factors and multiples which is proceeded with STEM approach to student's accusations]*. Master's thesis, Uşak University.

Ecevit, T., Yıldız, M., & Balcı, N. (2022). Türkiye'deki STEM eğitimi çalışmalarının içerik analizi [Content analysis of STEM education studies in Turkey]. Bolu Abant Izzet Baysal University Journal of Faculty of Education, *22*(1), 263-286.

Eshaq, H. A. (2024). The effect of using STEM education on students' mathematics achievement. *Journal of Pedagogical Research, 8*(1), 75-82. https://doi.org/10.33902/JPR.202423476

Genç, R. A. (2023). *Ortaöğretim fen eğitiminde STEM araştırmaları: Meta-sentez çalışması [STEM research in secondary science education: A meta-synthesis study]*. Master's thesis, Atatürk University.

*Gül, H. (2023). *Kavram karikatürü destekli FETEMM etkinliklerinin 7. sınıf matematik dersi sayılar ve işlemler ünitesinin öğretimi üzerindeki etkileri [The effects of concept cartoon supported FeTeMM activities on the teaching of the 7th grade mathematics lesson numbers and operations unit].* Master's thesis, Erciyes University.

*Gülbahar, N. (2023). *Matematik ağırlıklı STEM eğitiminin ilkokul öğrencilerinin matematik başarısına ve matematik tutumlarına etkisi [The effect of mathematics-headly stem education on math success and attempts of primary school students].* Master's thesis, Kocaeli University.

*Güler, E. (2024). *STEM temelli geometri etkinliklerinin öğrencilerin akademik başarılarına ve matematik tutumlarına etkisi [The effect of STEM-based geometry activities on students' academic achievements and mathematics attitudes].* Master's thesis, Kahramanmaraş Sütçü İmam University.

Gülhan, F. (2022). Türkiye'de yapılmış STEAM/[STEM+ A (Sanat)] araştırmalarındaki eğilimlerin analizi [Analysis of trends in researches on STEAM (STEM + Art) made in Turkey]. *Turkish Journal of Educational Studies*, *9*(1), 23-46.

Gümüş, B., & Eroğlu, E. (2024). Fen eğitiminde gerçekleştirilen STEM uygulamalarının farklı değişkenler açısından incelenmesi: bir meta analiz çalışması [Examination of STEM practices in science education in terms of different variables: A meta-analysis study]. *Trakya Journal of Education*, *14*(1), 54-74.

Günbatar, S. A., & Tabar, V. (2019). Türkiye'de gerçekleştirilen STEM araştırmalarının içerik analizi [Content analysis of science, technology, engineering and mathematics (STEM) research conducted in Turkey], *YYU Journal of Education Faculty*, *16*(1), 1054-1083.

Herdem, K., & Ünal, İ. (2018). STEM eğitimi üzerine yapılan çalışmaların analizi: Bir meta-sentez çalışması [Analysis of studies about STEM education: A Meta-synthesis study]. *Marmara University Atatürk Faculty of Education Journal of Educational Sciences, 48*(48), 145-163.

Hyacinth, E. (2019). *The effect of STEM and non-STEM education on student mathematics ability in third grade* (Doctoral dissertation, Walden University). Walden Dissertations and Doctoral Studies. https://scholarworks.waldenu.edu/dissertations/7809

*Kabakçıoğlu, E. B. (2023). *Gerçekçi matematik eğitimi ve STEM eğitim yaklaşımına göre matematik eğitiminin öğrencilerin matematik başarısı ve öğrenme kalıcılığına etkisi [Realistic mathematics education and the effect of mathematics education on students' mathematics achievement and learning retention according to the stem education approach]* Master's thesis, Aydın Adnan Menderes University.

Kalemkuş, J. (2020). Deneysel araştırmalarda STEM eğilimi. [STEM tendency in experimental researches]. Dicle University Journal of *Ziya Gökalp Faculty of Education, (36)*, 78-90.

*Karabörk, M. A. (2023). *Ortaokul matematik dersi kazanımlarının interdisipliner STEM yaklaşımıyla uyarlanması ve buna dayalı etkinliklerin etkililiğinin incelenmesi [Adaptation of acquisition of secondary school mathematics course with interdispliner STEM approach and analysis of activities' effectiveness based on this].* Doctorate Dissertation, Bolu Abant İzzet Baysal University.

*Karadeniz, H. (2019). *STEM uygulamalarının öğrencilerin STEM farkındalıkları üzerine ve 'üçgenler' ünitesindeki başarılarının kalıcılık düzeyine etkisi [The effect of STEM applications on the STEM perceptions of the students and the success of the success in the 'triangles' unit]*. Master's thesis, Bayburt University.

Kwak, H., & Ryu, H. (2016). Analysis on the research trends in STEAM education. *Journal of Science Education*, *40*(1), 72-89.

Lueangsuwan, T., & Srikoon, S. (2021). Meta-analysis of STEM Education approach effected on students' learning achievement in Thailand. *Journal of Physics: Conference Series, 1835*(1), 1–7. https://doi.org/10.1088/1742-6596/1835/1/012084

*Macun, Y. (2019). *Problem temelli STEM etkinliklerinin oran-orantı ve yüzdeler konularının öğretiminde 7. sınıf öğrencilerinin matematik başarılarına, tutumlarına ve görüşlerine etkisi [Effect of problem-based STEM activities on 7th grade students' mathematics achievements, attitudes, and views on teaching ratio-proportion and percentage]*. Master's thesis, Erciyes University.

Mandev, F. ve Yavuz, S. (2021). Fen, teknoloji, mühendislik ve matematik (FeTeMM) ile ilgili araştırmalar üzerine bir içerik analizi. [A Content analysis on research in science, technology, engineering and mathematics (STEM)]. *Karaelmas Journal of Educational Sciences, 10*(1), 27-46.

Mao, P., Cai, Z., He, J., Chen, X., & Fan, X. (2021). The relationship between attitude toward science and academic achievement in science: A three-level meta-analysis. *Frontiers in Psychology, 12*, 784068. https://doi.org/10.3389/fpsyg.2021.784068

Ministry of National Education [MoNE] (2016). *STEM education report.* Ministry of National Education General Directorate of Innovation and Educational Technologies.

Ministry of National Education [MoNE] (2024a). *Türkiye century education model curricula common text.* Access address: https://mufredat.meb.gov.tr/

Ministry of National Education [MoNE] (2024b). *Türkiye century education model middle school mathematics curriculum.* Access address: https://mufredat.meb.gov.tr/

Ministry of National Education [MoNE] (2024c). *Türkiye century education model high school mathematics curriculum.* Access address: https://mufredat.meb.gov.tr/

Moore, T. J., Glancy, A. W., Tank, K. M., Kersten, J. A., Stohlmann, M. S., Ntow, F. D., & Smith, K. A. (2013, 23-26 Haziran). *A framework for implementing quality K-12 engineering education*. In 2013 ASEE Annual Conference & Exposition, Atlanta, Georgia. 10.18260/1-2—19060

OECD (2016). *Innovating education and educating for innovation: The power of digital technologies and skills*. OECD.

*Özdemir, H. (2018). *Meslek lisesi öğrencilerinin alanlarıyla ilgili mesleki matematik başarısını geliştirmeye yönelik STEM uygulamaları [STEM (Science, technology, engineering, mathematics) implementations to improve the students' vocational mathematics success regarding their branch in vocational high schools]*. Doctorate Dissertation, Bursa Uludağ University.

Rahmatika, Z., Wiliyanti, V., Diani, R., Daenuri, E., & Putri, C. A. S. A. (2024). Science, technology, engineering, and mathematics (STEM) approach in physics learning: Meta-analysis study. *AIP Conference Proceedings, 3058*(1).

Riechert, S., & Post, B. (2010). From skeletons to bridges & other STEM enrichment exercises for high school biology. *The American Biology Teacher, 72*(1), 20-22. https://doi.org/10.1525/abt.2010.72.1.6

*Tekneci, S. (2024). *STEM destekli 3B blok kodlama araçlarının fen ve matematik başarısına, mühendislik, kodlama ve uzamsal görselleştirme becerisine etkisi [The effect of STEM-supported 3D block coding tools on science and mathematics achievement, engineering, coding and spatial visualization skills]*. Master's thesis, Giresun University.

Tezel, Ö., & Yaman, H. (2017). A review of studies on STEM education in Turkey. *Journal of Research in Education and Teaching*, *6*(1), 135-144.

Thalheimer, W., & Cook, S. (2002). *How to calculate effect sizes from published research articles: A simplified methodology*. Work-Learning Research.

Thomas, D. R., & Larwin, K. H. (2023). A meta-analytic investigation of the impact of middle school STEM education: Where are all the students of color? *International Journal of STEM Education, 10*(1), 43. https://doi.org/10.1186/s40594-023-00425-8

Tümkaya, S., & Ulum, H. (2020). A systematic review of the approaches enhancing the mathematics achievement. *Journal of Education Culture and Society*, *11*(2), 171-182.

TUSIAD (2014). *STEM alanında eğitim almış işgücüne yönelik talep ve beklentiler araştırması [Research on demand and expectations for labour force trained in STEM field]* https://tusiad.org/tr/yayinlar/raporlar/item/download/7014_d28ffa2adda423c6d3852cc01c965993

*Türk, E. F. (2023). *Eğitsel robot setleri ile gerçekleştirilen STEM etkinliklerinin ortaokul 5. sınıf öğrencilerinin matematik dersi başarılarına, problem çözme becerilerine ve STEM beceri düzeylerine etkisi [The effect of STEM activities performed with educational robot sets on middle school 5th grade students' mathematics success, problem solving skills and STEM skills levels].* Master's thesis, Amasya University.

Sümen, Ö. Ö. (2018). *Matematik dersinde uygulanan STEM etkinliklerinin sınıf öğretmeni adaylarının öğrenme ürünlerine etkileri [The effects of STEM activities in mathematics lessons on learning outcomes of pre-service elementary teachers].* Doctorate Dissertation, Ondokuz Mayıs University.

Şen, S., & Yıldırım, İ. (2020). *Meta-analysis applications with CMA.* Anı Publishing.

Wang, L. H., Chen, B., Hwang, G. J., Guan, J. Q., & Wang, Y. Q. (2022). Effects of digital game-based STEM education on students' learning achievement: A meta-analysis. *International Journal of STEM Education*, *9*(1), 26.

Wells, J. G. (2016). PIRPOSAL model of integrative STEM education: Conceptual and pedagogical framework for classroom implementation. *Technology and Engineering Teacher, 75*(6), 12-19.

Yıldırım, B., & Altun, Y. (2015). STEM eğitim ve mühendislik uygulamalarının fen bilgisi laboratuar dersindeki etkilerinin incelenmesi [Investigating the effect of STEM education and engineering applications on science laboratory lectures]. *El-Cezerî Journal of Science and Engineering, 2*(2), 28-40.

Zhang, X., & Skaalvik, E. M. (2021). Attitudes towards mathematics, achievement, and drop-out intentions among STEM and non-STEM students in Norway. *International Journal of STEM Education, 8*(1), 24. https://doi.org/10.1186/s40594-021-00275-5