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A Systematic Review of the Effects of STEM Education Practices at the Primary School Level

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SUMMARY

The purpose of this article is to examine the effects of STEM (Science, technology, engineering, and mathematics) education practices carried out at the primary school level in Turkey on various learning outcomes. The systematic review method was employed to accomplish this purpose. This study examined whether 30 comparisons from publications found through database searches and meeting the inclusion criteria revealed a significant difference. The analyses conducted led to a finding that STEM education used in primary schools had favorable and statistically significant effects on attitude towards STEM (f=6), academic achievement in a science course (f=5), 21st-century skills (f=2), interest in careers in STEM fields (f=2), scientific creativity (f=2), basic skills (f=2), entrepreneurial skills (f=1), social skill (f=1), reflections on the nature of science (f=1), STEM perception (f=1), and Scratch achievement (f=1). On the other hand, the study's findings showed that these practices did not produce a statistically significant difference in academic achievement in mathematics courses (f=1) and reflective thinking skills toward problem-solving (f=1). Additionally, the study's findings showed that 2 practices created a statistically significant difference in the positive direction on problem solving skills, and 2 practices did not create a statistically significant difference.

Keywords: STEM education practices, primary school, Turkey, effect, systematic review

INTRODUCTION

One of the most critical educational levels in the construction of the future of individuals is primary school. Effective learning experiences in primary school are of great importance for the individual's academic, professional, and daily life. In the current era, there has been an increased interest in teaching approaches that integrate various disciplines to improve learning outcomes at the primary school level. One of these approaches is the STEM education approach.

The word STEM was used for the first time in history by biologist Judith Ramaley from the American National Science Foundation in 2001 (Iliyasu et al., 2023; Kuchkarova, 2021). STEM education is an approach that integrates content and skills in science, technology, engineering, and mathematics in the teaching and learning process (Ithnin et al., 2017). When students are involved in STEM education, they learn gains integrated rather than separately (Akgunduz ve Ertepinar, 2019). STEM education is seen as a crucial engine of global innovation, economic development, and human opportunity (Glimps-Smith, 2023).

There have been a lot of studies done in the past on STEM education in primary schools (Akyar, 2021; Alkis Kucukaydin et al., 2024; Altin Zeybek, 2022; Atabas, 2020; Azgin & Senler, 2019; Balci, 2022; Bircan & Calisici, 2022; Hismi, 2022; Karalar et al., 2021; Ozkul, 2021; Ozturk, 2020; Tabaru, 2017; Turker, 2023; Ultay et al., 2020; Unlu, 2022; Yavuz, 2019; Yavuz & Yildiz Duban, 2021; Yildiz, 2022; Yurtbakan & Aydogdu-Iskenderoglu, 2023; Zengin et al., 2022). It was observed that some of these studies examined the effect of STEM education practices on various variables. These studies generally focused on the effects of STEM education practices on variables such as academic achievement, attitude toward STEM, problem-solving skills, and 21st-century skills. Although there are many studies on the subject, different results can be encountered regarding the effect of these studies. Therefore, it is thought that by systematically reviewing these studies, a certain inference about the practices' efficacy can be drawn.

To assess the status of previous studies, it is crucial to demonstrate the effect of STEM education practices in primary schools on the various variables. Additionally, such a study is thought to be important in terms of guiding the steps to be taken to improve STEM education practices in primary school.

It is seen that many studies have been conducted to determine the effectiveness of STEM education studies in Turkey using scientific synthesis methods (Ademoglu et al., 2021; Degerli & Yapici, 2022; Guder et al., 2022; Karasah-Cakici et al., 2021; Kazu & Kurtoglu Yalcin, 2021; Ormanci, 2020). For instance, the effect of STEM education on secondary school students' achievement in science courses was investigated in the study by Ademoglu et al., (2021). A description of the effect of STEM education on various learning outcomes of students at various levels was made in the study conducted by Ormanci (2020). The primary school fourth grade variable was also examined in the reviews made according to grade level in the study by Degerli & Yapici (2022) in which the impact of STEM education on the academic achievement of students was examined. Additionally, primary school level was also looked at as an education level variable in moderator analyses in studies looking at the effects of STEM education on students' scientific process skills (Guder et al., 2022; Kazu & Kaplan, 2024) and academic achievement in science courses (Karasah-Cakici et al., 2021). As can be seen, the primary school level is only included in the subgroup analysis in the studies, and these studies also focus on the effect of STEM education on only one variable. As a result, It has been noted that there isn't a synthesis study that comprehensively examines the results of STEM education practices used at the primary school level. In this direction, there is a need to examine the effects of STEM education practices carried out at the primary school level on various variables with scientific methods. In this context, the aim of the research is to examine the effects of STEM education practices at the primary school level in Turkey on various learning outcomes. The research sought answers to the following questions:

- What are the publication years of the research?
- What are the grade levels of the students participating in the research?
- What are the variables in which the effects of practices are examined in studies?
- What are the statistical significance states of the effects of practices in research?

METHOD

Research Design

A systematic review method was used in this study to examine the effects of STEM education practices used at the primary school level in Turkey on various learning outcomes. A systematic review allows to synthesis of the findings of studies seeking answers to the same research question (Dickson et. al., 2017; Newman & Gough, 2020; Trochim et. al., 2016).

Data Collection

The data of the study were obtained as a result of the scans made in Google Scholar and CoHE Thesis Center. In order to collect the data, the “STEM”, “FeTeMM”, “İlkokul”, “3. Sınıf”, “4. Sınıf”, Üçüncü Sınıf”, and “Dördüncü Sınıf” Turkish keywords were scanned with the option to be in the title of the publication. Additionally, for the scans made in English, it was requested that the keywords “STEM”, “Primary School”, “Elementary School”, “3rd Grade”, “4th Grade”, “Third Grade”, and “Fourth Grade” be in the title of the publication, and the keyword "Turkey" in the full text. The last search in the databases was carried out on 25 May 2023. The studies located through the database searches were examined, and those that satisfied the inclusion requirements were added to the meta-analysis. The criteria sought for the studies to be included in the meta-analysis are as follows:

- The study must have been carried out at the primary school level.
- The effect of STEM education practices on different variables should be examined in the study.
- The state of significant difference between the pre-test and post-test scores regarding the practices in the study should be stated.
- The STEM education practice must have been carried out in Turkey.
- The study should be aimed at students with normal development.
- The study should not contain the same findings from different publications (produced by each other).

Figure 1 displays the flowchart giving comprehensive details about the studies reached, excluded, and included.

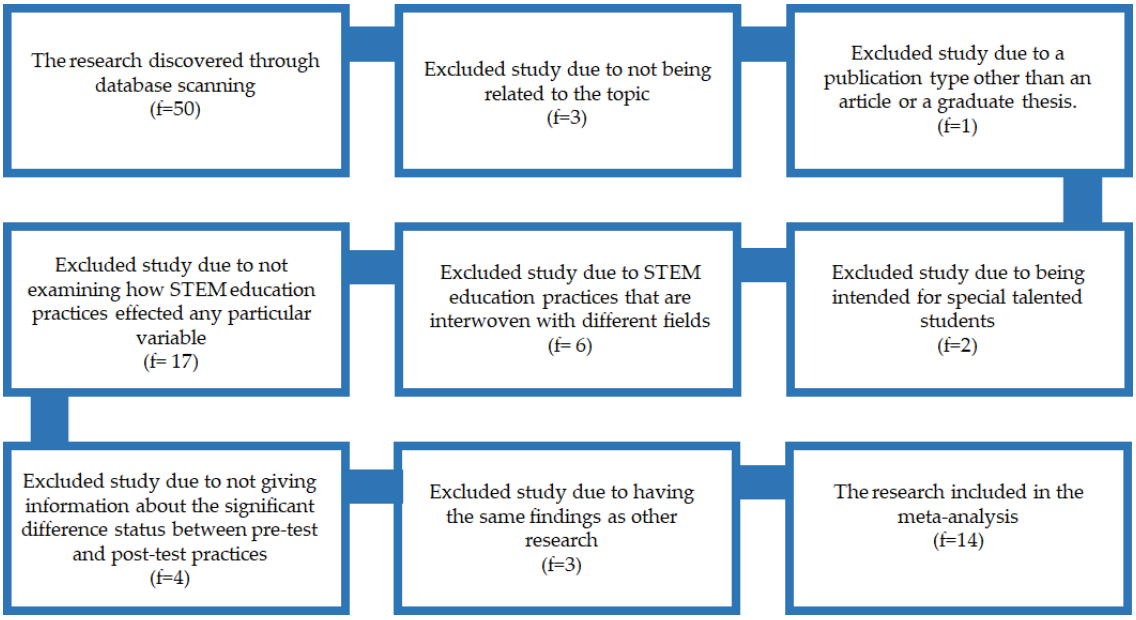

Figure 1. The Flowchart For Data Collection

As can be seen in Figure 1, 50 studies arrived at as a result of scans using the keywords identified in the databases. A total of 36 studies were excluded from the meta-analysis due to 3 studies being unrelated to the topic, 1 study having a publication type other than an article or graduate thesis, 17 studies not examining how STEM education practices effected any particular variable, 6 studies' STEM education practices that are interwoven with different fields, 2 studies being intended for special talented students, 4 studies not providing information about the significant difference, and 3 studies having the same findings as other research. Consequently, the meta-analysis included the 14 studies that remained after the eliminations. These studies have been collected into two articles, three doctoral theses, and nine master's theses.

Data Analysis

Content analysis was used in the analysis of the data of the studies included in the research. A "Study Classification Form" was created for the analyses. This form contains descriptive data regarding the studies. This information spans the study's publication year, the participants' class level, the variable whose impact was examined, and the status of that effect. The coding was performed twice on different days to check the reliability of the study, and the coding results were compared. The coding findings did not differ from one another.

FINDINGS AND DISCUSSION

The results in relation to the research questions and a discussion of the results are presented in this section.

Publication Year of Research

Table 1 gives the results of the analyses performed on the examination of the studies in terms of year of publication.

Table 1. Publication Year of Research

Publication year	Research
2017	Tabaru (2017)
2019	Yavuz (2019)
2020	Ozturk (2020), Ultay et al. (2020), Atabas (2020)
2021	Akyar (2021), Ozkul (2021)
2022	Altin Zeybek (2022), Balci (2022), Bircan ve Calisici (2022), Hismi (2022), Unlu (2022), Yildiz (2022)
2023	Turker (2023)

Table 1 indicates that the publication dates of the studies included in the study's scope changed between 2017 and 2023. It is seen that most studies (f=6) on the subject were published in 2022. 2020 (f=3) and 2021 (f=2) come after this one, respectively. Additionally, it is seen that 1 study each has been published on the subject in the years 2017, 2019, and 2023.

The findings show that the interest in studies to determine the effectiveness of STEM education at the primary school level has increased in recent years. Other current synthesis studies on STEM education also support this study and show that there is an increasing trend in the number of research on the subject from the past to the present (Hebebci, 2023; Ilma et. al., 2023; Noris et. al., 2023). It can be thought that the increasing importance of the interdisciplinary approach in teaching plays a role in achieving these results. Additionally, it is thought that nations and educators may have been interested in the advancements that have changed the world in the domains of science, technology, engineering, and mathematics.

Student Grade Levels Participating in Practice in Research

The findings of the analyses carried out about the examination of the studies in terms of the grade level of the students taking part in the practice are presented in Table 2.

Table 2. Student Grade Levels Participating in Practice in Research

Grade Level	Research
Third grade	Balci (2022), Ozkul (2021), Turker (2023), Ultay et al. (2020)
Fourth grade	Bircan ve Calisici (2022), Unlu (2022), Ozturk (2020), Akyar (2021), Hismi (2022), Tabaru (2017), Yildiz (2022), Altin Zeybek (2022), Yavuz (2019), Atabas (2020)

Table 2 shows that the majority of the studies (f=10) included for the research's scope are for primary school students in the 4th grade. On the other hand, STEM practices were carried out in the third grade of primary school in four research.

When the studies were examined according to the grade level, it was seen that most studies were done at the 4th grade level. It can be argued that these results were due to the perception that multidisciplinary practices at higher grade levels were simpler to use.

The Variables on Which the Practices' Effect Were Examined in Research

Table 3 gives the results of the analysis performed about the examination of the studies in terms of the variables on which the practices' effects were examined.

Table 3. The Variables on Which The Practices' Effect Were Examined in Research

Variable	Research
Academic Achievement	Ozturk (2020), Hismi (2022), Tabaru (2017), Altin Zeybek (2022), Ultay et al. (2020), Bircan & Calisici (2022)
Attitude towards STEM	Unlu (2022), Hismi (2022), Turker (2023), Bircan & Calisici (2022), Balci (2022), Yavuz (2019)
Problem-solving skills	Hismi (2022), Tabaru (2017), Balci (2022), Türker (2023)
21st-century skills	Bircan & Calisici (2022), Yildiz (2022)
Interest in careers in the STEM fields	Ozkul (2021), Yavuz (2019)
Scientific creativity	Turker (2023), Atabas (2020)
Basic skills	Tabaru (2017), Ozkul (2021)
Entrepreneurial skills	Akyar (2021)
Social skill	Hismi (2022)
Reflections on the nature of science	Yildiz (2022)
STEM perception	Yavuz (2019)
Scratch achievement	Bircan & Calisici (2022)

Reflective thinking skills toward problem-solving	Atabas (2020)

When Table 3 is looked at, it can be noted that the studies included in the research look at the effects of STEM education practices in primary schools across a total of 13 variables. Academic achievement and attitude toward STEM are the variables that have been observed the most. Problem solving skills and 21st century skills follow. Furthermore, it is seen that there are two studies each focusing on interest in careers in the STEM fields, scientific creativity, and basic skills. On the other hand, it is seen that there is one study each examining entrepreneurial skills, social skill, reflections on the nature of science, STEM perception, Scratch achievement, and reflective thinking skills toward problem solving.

When the included studies were reviewed, it became clear that the practices mainly focused on academic achievement and attitude towards STEM. The ultimate objective that parents, teachers, students, the government, and other stakeholders in the education industry expect is an academic achievement (Ukpanah & Ekpo, 2022). An attitude is an evaluation or feeling about an object that can be positive or negative (Chaihanchanchai & Anantachart, 2023). It can be said that researchers are curious about the effects of STEM education practices on both cognitive and affective characteristics in the learning-teaching process.

Statistical Significance Situations of the Effects of Practices in Research

The findings of the analyses carried out in relation to the examination of the studies in terms of statistical significance situations of the effects of practices are presented in Table 4.

Table 4. Statistical Significance Situations of The Effects Of Practices in Research

Variable		**Statistical significance situations of the effect**	**Research**
Academic Achievement	Science course	Statistically significant	Ozturk (2020), Hismi(2022), Tabaru (2017), Ultay et al. (2020), Altin Zeybek (2022)
	Mathematics course	Not statistically significant	Bircan & Calisici (2022)
Attitude towards STEM		Statistically significant	Bircan & Calisici (2022), Unlu (2022), Hismi (2022), Turker (2023, Balci (2022), Yavuz (2019)
Problem-solving skills		Statistically significant	Hismi (2022), Turker (2023)
		Not statistically significant	Tabaru (2017), Balci (2022)
21st-century skills		Statistically significant	Bircan & Calisici (2022), Yildiz (2022)
Interest in careers in the STEM fields		Statistically significant	Ozkul (2021), Yavuz (2019)
Scientific creativity		Statistically significant	Turker (2023), Atabas (2020)
Basic skills		Statistically significant	Tabaru (2017), Ozkul (2021)
Entrepreneurial skills		Statistically significant	Akyar (2021)
Social skill		Statistically significant	Hismi (2022)
Reflections on the nature of science		Statistically significant	Yildiz (2022)
STEM perception		Statistically significant	Yavuz (2019)
Scratch achievement		Statistically significant	Bircan & Calisici (2022)
Reflective thinking skills toward problem-solving		Not statistically significant	Atabas (2020)

The statistical significance limit was accepted as p=0.05 and all significant effects were in favor of the posttest.

When Table 4 is looked at, it can be seen that STEM education practices in primary schools make a statistically significant difference in the positive direction on the academic achievement of the science course but not a statistically significant difference on the academic achievement of the mathematics course. Additionally, the practices have statistically significant positive effects on attitude towards STEM, 21st century skills, interest in careers in the STEM fields, scientific creativity, basic skills, entrepreneurial skills, social skill, reflections on the nature of science, STEM perception, and scratch achievement. On the other hand, it is observed that the two apps produce a statistically significant difference in the positive direction on problem-solving abilities, but the two applications do not produce a significant difference. Furthermore, the applications did not create a statistically significant difference on reflective thinking skills toward problem solving.

The results generally show that STEM education practices in primary schools have a positive and noteworthy effect on an extensive number of variables. It is thought that the diversity in the content of STEM education practices and the student profiles involved may result in a range of results in terms of the practices' influence. Practices may be insufficient in the development of some characteristics of students. This idea has been supported by some research that has concentrated on student characteristics and instructional practices in enhancing STEM education-related components (Arshad, Halim, & Nasri, 2021; Oner & Capraro, 2016; Uluduz & Calik, 2022).

CONCLUSION

This study attempted to identify the effects of STEM education practices used at the primary school level in Turkey on various learning outcomes. The research's scope was constrained to studies that met the criteria for inclusion. STEM education practices are effective on a wide range of variables, according to this study. These variables include attitude towards STEM, academic achievement in a science course, 21st-century skills, interest in careers in STEM fields, scientific creativity, basic skills, entrepreneurial skills, social skill, reflections on the nature of science, STEM perception, and Scratch achievement. However, these practices do not effectively develop reflective thinking abilities for solving problems and academic achievement in mathematics courses. Furthermore, STEM education practices improved problem-solving abilities in two studies while failing to do so in the other two.

This study enabled certain insights to be drawn regarding the effect of STEM education in primary school. More research is recommended to better understand the effects of STEM education practices in primary schools. The next studies could focus particularly on problem-solving and academic achievement in mathematics courses.

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