Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi
Cilt 16, Sayı 1, Haziran 2022, sayfa 17-48. ISSN: 1307-6086
Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education
Vol. 16, Issue 1, June 2022, pp. 17-48. ISSN: 1307-6086

Research Article

The Effect of STEM Approach in Science Education on Academic Achievement: A Meta-Analysis Study

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Received : 23.03.2022 Accepted : 15.05.2022

Doi: 10.17522/balikesirnef.1092035

Abstract - In this research, a meta-analysis study was carried out to investigate the effect of the STEM approach in science education in Turkey on academic achievement of students. In accordance with the criteria determined in the meta-analysis study, the studies included in the research are at the Master's and doctoral levels, and these studies were taken from the National Thesis Center database of the Council of Higher Education. In the study, a total of 147 studies carried out between 2010 and 2020 were examined and 31 Master's and 3 Doctoral thesis studies fit the criteria of inclusion were included in the meta-analysis. The sample of a total of 34 studies consisted of 1962 students at the 4th, 5th, 6th, 7th and 8th grade levels. Analyses were made with the help of Comprehensive Meta-Analysis V2 statistical program. The random effects model was used because the structure was heterogeneous when the studies were analysed and combined. As a result of the research, the effect size of the STEM approach in science education on students' academic achievement was calculated as 1.420. So, this value has a large effect size. In this context, it has been concluded that the STEM approach in science education has a positive and large effect on increasing the academic achievement of students. The effect size on academic achievement differed according to the grade level, and the highest effect was observed in the studies at the 4th grade level.

Keywords: STEM, science, academic achievement, meta-analysis

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Introduction

The fact that science and technology change and develop in a way that competes with time has made it necessary to be in a state of constant renewal in the age we live in. Countries that are able to adapt to these changes and developments and therefore constantly innovate and develop their needs in this direction have always managed to be one step ahead of other

countries in all fields, especially in economy. The economic well-being of a society is directly related to the education system of that society. Because, powerful countries are referred to as countries that can both use and develop these technologies without ignoring the changes in science and technology by keeping their education systems in the foreground. In the globalizing world, the economic competition of countries, rapidly developing science and technology will affect our lives in the future more than today (MEB, 2006). Therefore, the ongoing varies and advancements in science and technology affect the education field, and changes in the field of education also affect science and technology (Selvi & Yıldırım, 2017). These innovations in the current era have also increased the need for qualified manpower. In this process, it is expected that education will serve to meet the needs of employment, manufacturing, innovation and qualified workforce, as in many sectors (Bybee, 2010; Dugger, 2010). Countries with high skilled labor standards are always one step ahead of other countries in other fields, especially in economy. One of the main causes for this situation is that the countries in question realize the importance of the interaction between science, technology and education, develop their education policies in line with their needs, and especially constantly update their science and mathematics education programs in pursuance of the needs of the developing age (Selvi & Yıldırım, 2017). It is of great importance that individuals acquire 21st century skills such as innovation, problem solving, group work, communication, critical thinking and research, especially in order to keep up with the rapidly developing science and technology in our age (Aydın, Saka, & Guzey, 2017). Therefore, the education of individuals who will be employed in the future is also a very important issue. Although it is purposed to raise persons who are adequate in the fields of science, technology, engineering and mathematics in order to take a place in the global economic race, it is stated that education has a serious task in raising these individuals (Akgündüz, 2016; Bybee, 2010; OECD, 2017).

STEM is a concept obtained by bringing together the acrostics of the words Science, Technology, Engineering, Mathematics (Moomaw, 2013). It is an approach put forward by the United States of America (USA) in the early 1990s to integrate the disciplines of science, mathematics, engineering and technology (Sanders, 2009). STEM education is an interdisciplinary teaching approach that combines the fields of science, technology, engineering and mathematics and ensures that these disciplines are taught in relation to each other (Roberts, 2012; Wang, Moore, Roehrig, & Park, 2011).

STEM education mainly purposes to provide students with some skills that individuals need to learn and develop in the current age (Bybee, 2013; Thomas, 2014). These skills, which are called 21st century skills; are referred to as learning and innovation skills (creativity and innovation, problem solving, communication, critical thinking, collaboration); information, media and technology skills (information literacy, media literacy, "Information, Communication and Technology" literacy); life and career skills (flexibility and adaptability, assertiveness and self-management, social and intercultural skills, leadership and responsibility, productivity and accountability) (Partnership for 21st Century Learning, 2007).

STEM education is very important for Turkey's economic competitiveness (Corlu, Capraro, & Capraro, 2014). As a matter of fact, the results of Turkey's international exams such as PISA (Programme for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study) reveal Turkey's need for STEM education. According to the 2015 TIMSS results, it is seen that Turkey's science and mathematics achievement is lower than the scale average at all levels, while according to the 2018 PISA results, Turkey's science and mathematics achievement is below the average of OECD countries (Okulu, 2019). Having to compete with these countries at every point, Turkey's results from international exams are seen as a problem (Acar, 2018; Aydeniz, 2017; Çolakoğu & Gökben, 2017; Elmalı & Balkan Kıyıcı, 2017; Gülhan, 2016; Okulu, 2019).

Many countries such as USA, England, Singapore and South Korea attach great importance to STEM education for being successful in PISA / TIMSS exams. When the education systems of the countries that are successful in these exams and are in the first place are examined, it is seen that most of these countries integrate STEM education with their curriculum (Yıldırım, 2018). It is aimed to strengthen STEM education in the MEB 2015-2019 Strategic Plan (MEB, 2015). In the STEM Education Report prepared by the Ministry of National Education, the following were suggested; STEM education should be given to all students, STEM education action plan can be developed together with institutions/organizations such as universities, TUBITAK and TUSIAD, STEM centers can be established and in-service trainings can be given to teachers there, and the content of the courses in the curriculum can be reduced gradually. Also, it is emphasized that transition to stage STEM education can be made (MEB, 2016). It is seen that science, engineering and entrepreneurship practices were included in the 2018 Science Curriculum in a different way from previous years (MEB, 2018).

In the recent past, a remarkable increase has been observed in studies on STEM education in our country (Aysu, 2019; Gülseven, 2020; Ozan 2019; Özaslan, 2019; Soysal, 2019). Studies conducted to measure the effectiveness of these studies and to evaluate the studies in general as a whole are rare. In this respect, it is thought that the meta-analysis study obtained from studies measuring the effect of STEM approach on science education in our country will contribute to the relevant literature. It is thought that this study will be useful in terms of describing the results of master's and doctoral thesis studies conducted between 2010-2020 and in accordance with the research criteria and evaluating the situation as a whole.

In this study, it is aimed to reveal the effectiveness of the STEM approach on the academic achievement of students in science education. In this respect, it is aimed to examine the studies conducted in our country in line with the STEM approach between 2010 and 2020 through meta-analysis. In the direction of this main purpose, answers to the following questions were sought.

I. How is the effect of STEM approach used in Science education on academic achievement of students?

II. In terms of grade level, is there a remarkable difference between the effect sizes of the STEM approach used in science lessons on the academic achievement of students?

Method

Research Model

Due to the rapid increase of studies conducted today, even experienced experts have difficulty in following these studies. Therefore; a meta-analysis method was developed in order to help to understand the information, to gather the results of more than one study, to reach a general conclusion and to enable the data to be analysed quantitatively (Walker, Hernandez, & Kattan, 2008). Meta-analysis is a method used to reach a generalization from the results of these studies by evaluating the researches conducted for a specific purpose or subject as a whole (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz, & Demirel, 2016). Its' difference from other literature review methods is that it is based on statistical methods in bringing together, integrating and analysing research findings (Durlak, 1995). Meta-analysis is simply the analysis of other analyses. It brings together the results of other studies in a coherent way (Cohen & Manion, 2001; Wolf, 1986).

With this method; individual studies carried on at several times, in different places and with different sample groups can be combined to reach more general, safer and more valid

results. This result is statistically stronger than an analysis of any single study due to an increased number of subjects, diversity in any subject or cumulative effects and results (Dinçer, 2021).

Given the ever-increasing amount of new information, the use and value of this method will likely increase. To achieve this, those are needed: variables, outcomes and goals should be well defined; to be able to access to appropriate and well-documented studies; in identifying and selecting the research, prejudgement and bias should be evaluated, heterogeneity should be determined, and a sensitive analysis should be performed (Rosenthal & Dimatteo, 2001).

As in every study, there are some steps to be followed for conducting the study in a healthy way, to review all the necessary steps in a planned manner and to do it in a sequence while doing meta-analysis. If the determined steps are followed, more distance can be taken by spending less time.

Steps of Meta-Analysis

The stages of meta-analysis can be listed as determining the aims and objectives of the research, literature review, coding, calculation of effect size, statistical model selection and analysis, and finally results and comments.

Determining the Purpose and Objectives of the Research

First of all, the problem of the research should be determined and hypotheses suitable for the problem should be established (Camnalbur, 2008).

Literature Review

In a meta-analysis study, it is recommended to use many of the literature review methods together when conducting a resource research on any subject (Şahin, 2005).

Coding Studies

One of the considerable issues in the coding process is the creation of a general coding system that can cover the data found in all the studies to be used in the study and the creation of a special coding system that can show the unique characteristics of the studies (Şahin, 2005).

Calculation of Effect Sizes

Effect size is defined as a value used for calculation of relation strength and its direction in a study. Developed by Cohen in 1988, this element is defined as the heart of meta-analysis (Kaşarcı, 2013).

Statistical Model Selection and Analysis

Since the determination of the statistical model related to the research results may change, model selection is of great importance in order to obtain reliable results and reach a general judgment. This model to be used also affects how the statistical analysis will be done and how the results will be interpreted (Camnalbur, 2008).

Results and Findings

After performing aforesaid processes meta-analysis studies are interpreted and made into report.

Data Collection

In this meta-analysis study, the subject of which has the effect of STEM approach on academic achievement in science education, the theses published on the research subject were searched in the database of the National Thesis Center of the Council of Higher Education in order to determine the studies included in the research. When the studies acquired as a result of the scans were investigated, thesis studies were preferred to be included in the analysis and coding was made. Some of the studies were not comprised in the analysis because they were not experimental studies and some did not contain enough data to analyze. As a result, the sample of the meta-analysis study consists of 34 postgraduate thesis studies examining the effect of STEM approach on academic achievement in science education.

Criteria in Study Selection

The criteria adhered to in study selection were examined under two headings as inclusion and exclusion criteria.

Inclusion Criteria

Experimental and quasi-experimental studies that contain sufficient data (sample sizes, averages and standard deviations of the groups) to calculate the effect size investigating the effect of the STEM approach on academic achievement in science education in the theses for which publication permission was granted in the National Thesis Center were included in the analysis. Apart from this, the criteria determined for the studies included in the study can be listed as follows.

- The study must have been done between 2010-2020
- It must be a PhD/Master's thesis,

• In real experimental and quasi-experimental designs, pretest-posttest model with control group must be used,

• It must include sample size, mean and standard deviation values,

• It must have clearly investigated the effect of the STEM approach on student achievement/academic achievement,

• The studies must have taken place in Turkey and the language must be Turkish.

In some studies, more than one data was taken because there was more than one experimental group or achievement test.

Exclusion Criteria

The fact that a study is not included in the meta-analysis in the current study is due to the fact that the study is not within the research limits or does not have the necessary statistical data for meta-analysis (Lipsey & Wilson, 2001; Wolf, 1986). Therefore, studies that did not meet the inclusion criteria were excluded from studies to be used for meta-analysis.

Characteristics of the Study (Dependent and Independent Variables)

There are cause-effect relationships in dependent and independent variables (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz, & Demirel, 2016). In meta-analysis studies, the effect that creates the effect sizes is the independent variable, and the resulting effect size is the dependent variable (Cohen, 1988). The 34 studies reached were carefully examined in regards to content and data. The characteristics that are thought to have an impact on the study were taken as the independent variable. In the general research problem, the independent variable can be expressed as the teaching approach. For theses researched in terms of academic achievement; grade level is the independent variable, and the dependent variable is the academic achievement level.

Coding Studies

A clear and detailed coding system should be developed for the studies included in the meta-analysis. The coding system used in the research consists of three parts. The first part is the “work identity”. This section contains information such as the identification number of the study, the name of the study, the name of the author, and the year of the study in order to identify the study. The second part is the “study content”. In this section, information such as the course and education level in which the STEM approach is applied are given. The third part is “study data”. In this section, information about the sample size, means and standard deviation values obtained from the experimental and control groups in the studies were

determined. The data in the studies were processed in pursuance of the coding form. In this study, the coding form created in accordance with the purpose of the study includes study code, year, type of thesis, test types used, sample numbers of control and experimental groups, mean and standard deviation data.

Data Analysis

The analysis of the study was made under two headings. First, descriptive statistics were made and reported. Then, the data were analyzed using the meta-analysis method. The operation efficiency technique, which is used in cases where arithmetic means that cannot be obtained from the same scale, are used while performing the analysis (Cohen, 1988; Lipsey & Wilson, 2001). This technique was developed by Glass (1976) and is used more in psychology, social sciences and educational sciences. The purpose of this is to reveal the difference between the mean of the experimental and control groups in experimental studies (Hunter & Schmidt, 1990). Transaction effect meta-analysis uses the standardized effect size denoted by the symbols “d”, “g” or “ES”. The effect size is found by dividing the difference between the mean of the experimental group and the control group by the total standard deviation. There are different coefficient classifications in the literature for effect size classification (Cohen, 1988; Thalheimer & Cook, 2002).

According to Cohen (1988), if the effect size is at the level of 0.20 - 0.49, it is defined as small; if it is at the level of 0.50 - 0.79, it is medium; if it is at the level of 0.8 and above, it is defined as large. According to Thalheimer and Cook (2002) it is interpreted as large at - 1.09 level, very large at 1.10-1.44 level, excellent effect at 1.45 level and above.

The Comprehensive Meta-Analysis (CMA) program was used in the analysis of the data. Analyses were made by choosing the format in which standard deviation, mean and sample sizes were entered as data in the CMA program. The significance level of the analyses was determined as 0.05. First, the effect sizes of individual studies that met the inclusion criteria in the meta-analysis were calculated. Hedges's g coefficient was used to calculate the effect sizes. Then, heterogeneity test was performed to determine the model to be applied. The random effects model used in heterogeneous studies was chosen, concluding that the study was heterogeneous, as both the p value was significant and the Q value was larger in the range where the df value coincided with the X^2 critical table comparison. The overall effect size was computed according to the random effects model. After these procedures, the analysis is largely completed. The next step is to prepare the necessary graphics and tables. The publication bias test of the subsequent meta-analysis is performed with different statistical

methods. In publication bias, the funnel plot is evaluated first. Since funnel plot interpretation is a highly subjective process, publication bias statistics are also needed. One of them is Rosenthal's Protected N statistic. Here, Classic fail-safe N statistic expresses how many studies with zero effect value should be included in the analysis in order for the p value to be greater than the alpha value, that is, to remove the significance. It is also called the fault protection number. In addition, Orwin's fail-safe N statistic computes the number of studies required to bring this effect to zero by looking at the average effect size. In other words, while the critical value for Rosenthal is the p value, it is the effect size for Orwin (Dinçer, 2021).

Findings

In this section, the descriptive statistics of the studies included in the research as a result of the literature review and the findings related to the individual and combined effect sizes obtained by the meta-analysis method are given.

The main purpose of the meta-analysis study is to calculate the effect size of the STEM approach in science education on the academic achievement of students. In this context, studies that met the inclusion criteria were analyzed and interpreted by including the findings related to these analyzes.

Findings Related to Descriptive Statistics

As a result of the literature review, 147 studies examine the effects of the STEM approach in science education on the academic achievement of students between the years 2010-2020 were reached. 34 studies were included in the study because they contained sufficient statistical data and met the inclusion criteria.

Table 1. Proportions of Theses Included in the Study

Publication Type	Studies Reached	Studies Included into Meta-Analysis	Studies Excluded	Proportions of Studies Included (%)
Master's	130	31	99	23,85
PhD	17	3	14	17,65
Total	**147**	**34**	**113**	**41,50**

When Table 1 was examined, as a result of the literature review, a total of 147 studies, 130 master's theses and 17 doctoral theses, were reached. 23.85% of master's theses, 17.65% of doctoral theses and 41.50% of all accessed studies were included in the analysis.

Descriptive statistics related to the studies about the effect of STEM approach in Science education on student's academic achievement are given in tables.

Table 2. Frequencies of Theses related to Study Types

Publication Type	Frequency (f)	Percentage (%)
Master's	31	91,17
PhD	3	8,83
Total	**34**	**100**

There are 31 (91.17%) master's thesis studies and 3 (8.83%) doctoral studies included in the meta-analysis study within the scope of academic achievement variable. In addition, a total of 5 data were obtained from 2 master's thesis studies and 2 data from 1 doctoral thesis study, and 39 data from 34 studies in total were included in the analysis. The total number of samples in these studies was 1962 people, including the experimental and control groups.

Table 3. Distribution of Theses by Years

Publication Year	Frequency (f)	Percentage (%)
2010	-	-
2011	-	-
2012	-	-
2013	-	-
2014	1	2,94
2015	-	-
2016	-	-
2017	2	5,88
2018	9	26,47
2019	18	54,94
2020	4	11,77
Total	**34**	**100**

It is observed that the theses included in the meta-analysis study within the scope of the academic achievement variable were made mostly in 2019, with 18 (54.94%) theses.

Table 4. Distribution of Theses by Grades

Grade Level	Frequency (f)	Percentage (%)
Grade 4	2	5,88
Grade 5	5	14,71
Grade 6	9	26,47

Grade 7	12	35,29
Grade 8	6	17,65
Total	**34**	**100**

It attracts attention that 12 (35.29%) of 34 theses included in the meta-analysis within the scope of the academic achievement variable were studies with 7th grade students. The least number of studies is the 4th grade level with 2 studies with a rate of 5.88%.

Table 5. Distribution of Sample Numbers of Theses

Sample Number	**Frequency (f)**	**Percentage (%)**
1<N<50	19	55,88
50<N	15	44,12
Total	**34**	**100**

The sample number of 34 thesis studies (the sum of the sample numbers of the experimental and control groups) that examined the effects of the STEM approach in science education on the academic achievement of students in science lessons included in the research was 1962. While the studies with a sample number of up to 50 people consisted of 19 thesis studies with 55.88%; The number of studies with more than 50 samples was determined as 15 (44.12%).

Findings Related to Effect Size

In this section, in order to test the sub-problems, the individual and general effect sizes of the data (number of samples, standard deviation and arithmetic mean) taken from the studies included in the research are calculated with the CMA program and the publication biases of the studies in the research sample were tested.

The publication bias is given in Table 6 by calculating the individual and general effect sizes of 39 data obtained from 34 studies that met the inclusion criteria in the meta-analysis study on the effect of the STEM approach in science education on the academic achievement of students.

Table 6. Findings on Individual Effect Size at 95% Confidence Interval of Studies

No	***Study Code***	***Hedges's g***	***Lower Limit***	***Upper Limit***	***p***
1.	CEYLAN,2014A	0,898	0,355	1,440	0,001
2.	CEYLAN,2014B	0,859	0,318	1,399	0,002
3.	PARLAKAY, 2017	0,732	0,231	1,233	0,004
4.	SARICAN, 2017	0,408	-0,178	0,995	0,172
5.	GAZIBEYOGLU, 2018	0,576	0,029	1,122	0,039

6.	DOGANAY, 2018	2,206	1,429	2,982	0,000
7.	DEDETURK, 2018A	1,060	0,727	1,392	0,000
8.	DEDETURK, 2018B	3,167	2,699	3,635	0,000
9.	KARCI,2018	0,649	0,085	1,213	0,024
10.	NAGAC, 2018	0,298	-0,288	0,884	0,319
11.	ACAR, 2018A	1,446	0,784	2,107	0,000
12.	ACAR, 2018B	1,571	0,924	2,218	0,000
13.	KOCA, 2018	1,326	0,573	2,079	0,001
14.	CALISICI,2018	0,930	0,318	1,542	0,003
15.	HIGDE, 2018	2,768	1,949	3,587	0,000
16.	IRAK, 2019	0,387	0,119	0,654	0,005
17.	NECCAR, 2019	-0,253	-0,886	0,381	0,434
18.	CIMENTEPE, 2019	1,652	0,984	2,320	0,000
19.	OZAN, 2019	0,895	0,010	1,779	0,047
20.	BUYRUK, 2019	0,288	-0,244	0,820	0,289
21.	DOGAN,2019	0,616	0,185	1,048	0,005
22.	CETIN,2019	4,981	3,732	6,230	0,000
23.	SEN, 2019	0,813	0,087	1,539	0,028
24.	KURT, 2019	1,141	0,334	1,947	0,006
25.	AKKAYA 2019	2,495	1,678	3,312	0,000
26.	TASCI, 2019A	3,226	2,436	4,015	0,000
27.	TASCI, 2019B	2,074	1,430	2,718	0,000
28.	TASCI, 2019C	2,460	1,771	3,148	0,000
29.	BUYUKBASTIRMACI, 2019	6,933	5,789	8,078	0,000
30.	SOYSAL, 2019	0,843	0,363	1,324	0,001
31.	BAHSI, 2019	0,915	0,198	1,632	0,012
32.	AYSU, 2019	2,675	2,005	3,345	0,000
33.	OZLEN, 2019	0,003	-0,560	0,565	0,992
34.	KAYABAS, 2019	0,932	0,305	1,559	0,004
35.	IZGI, 2020	1,251	0,653	1,849	0,000
36.	OZASLAN, 2019	0,698	0,220	1,176	0,004
37.	OZTURK, 2020	2,446	1,705	3,188	0,000
38.	GULSEVEN, 2020	1,053	0,535	1,570	0,000
39.	GUVEN, 2020	0,445	-0,173	1,064	0,158

It is seen in Table 6, the individual effect size, lower-upper limits and p values of 39 data obtained from a total of 34 studies were calculated. When the hedges's values in the comparison are examined, only Neccar's (2019) study has a negative effect size. The reason for this can be explained as the result of the research against the experimental group. Apart from this, when the lower and upper limits are examined, the lowest lower limit is -0.886; the highest upper limit was calculated as 8,078.

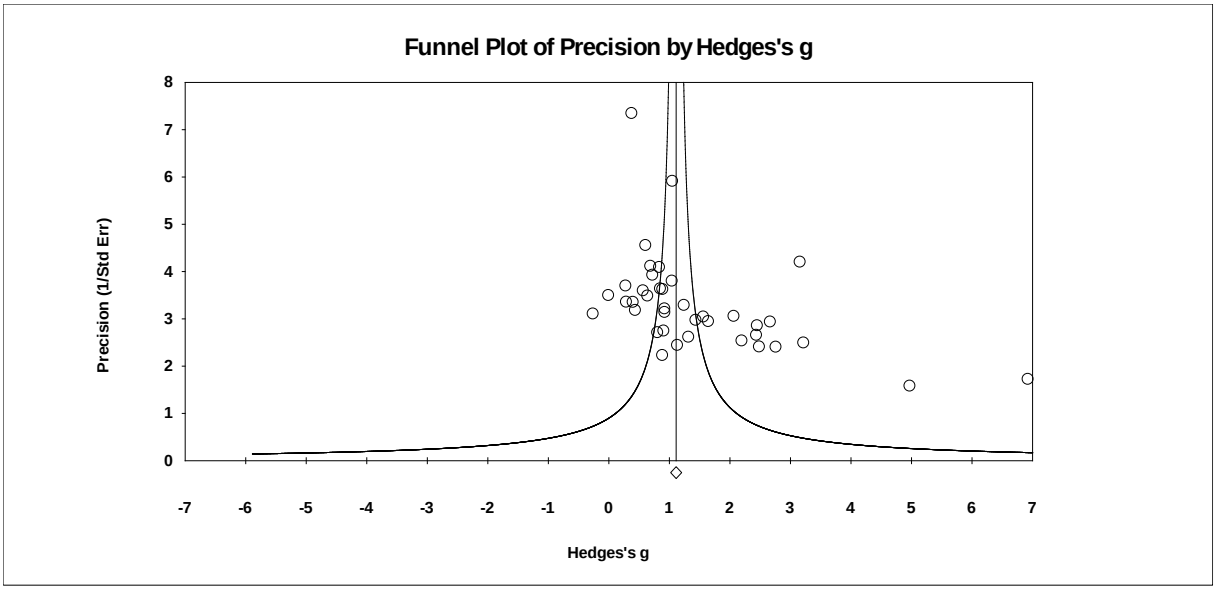

Figure 1. Distribution Funnel Plot of Effect Sizes According to Hedges' g Value Related to Studies

It is also necessary to calculate the overall effect size of the studies for which individual effect size calculations are made. It is great importance to control the heterogeneity of studies before calculating the overall effect size. Because the selection of the model to be used is determined at this step. In this context, the individual effect size funnel plot in Figure 1 needs to be interpreted. When the funnel graph is examined, individual studies are shown as a circle and the overall effect level is shown as a diamond. Individual studies are expected to be between the slope lines in the graph. However, it is seen that some studies are outside the slope lines. The fact that most of the individual studies are located within the slope line gives the interpretation that the study has a heterogeneous structure. However, this comment alone is not sufficient. Therefore, it is necessary to look at the Q and p values in order to interpret the heterogeneity situation objectively (Dinçer, 2021).

Table 7. Heterogeneity Test of Studies

Heterogeneity				***Tau-squared***			
Q-value	df (Q)	P-value	I-squared	TauSquared	StandardError	Variance	Tau
443,651	38,000	0,000	91,435	0,917	0,273	0,075	0,958

When Table 7 is examined, the Q value was computed as 443,651 as a result of the heterogeneity test. This value was found to be between 49,802-55,708 at the 95% significance level of 38 degrees of freedom in the X^2 table. Accordingly, the fact that the Q value is higher than the critical value range in the X^2 table (X^2=49,802-55,708 for df=38) shows that the

studies included in the meta-analysis have a heterogeneous structure. If the result of the heterogeneity test is significant, the random effects model should be used (Dinçer, 2021).

The overall effect sizes of the fixed and random effects models of the studies included in the meta-analysis are given in Table 8.

Table 8. General Effect Sizes for the First Sub-Problem

Model	***N***	***Standard Error***	***Hedges's g***	***%95 Confidence Interval***		***Z-value***	***p-value***
				Lower Limit	***Upper Limit***		
Fixed	*39*	0,047	1,112	1,021	1,203	23,871	0,000
Random	39	0,163	1,420	1,101	1,738	8,738	0,000

The overall effect size was computed primarily according to the fixed effects model and was measured as 1.112 with a standard error of 0.047. However, as a result of the heterogeneity test obtained from the studies included in the meta-analysis, the model to be used in the calculation of the overall effect size was chosen as the random effects model.

As a result of the analysis of the random effects model, the overall effect size value was computed as 1,420 with a standard error of 0.163. It is seen that the effect size has a lower limit of 1,101 and an upper limit of 1,738 in the 95% confidence interval. The positive value of the overall effect size indicates that this effect is in favor of the experimental groups using the STEM approach. In addition, the calculated z value of 8,738 was found to be statistically remarkable with p=0,000. A P value less than 0.05 shows that there is a remarkable difference between the groups. According to the findings obtained in this direction, it can be interpreted that the STEM approach in science education has a positive and large effect on increasing the academic achievement of students (Dinçer, 2021).

The forest graph showing the distribution of Hedges's g effect sizes of the studies taken within the scope of the study and examining academic achievement is given in Figure 2.

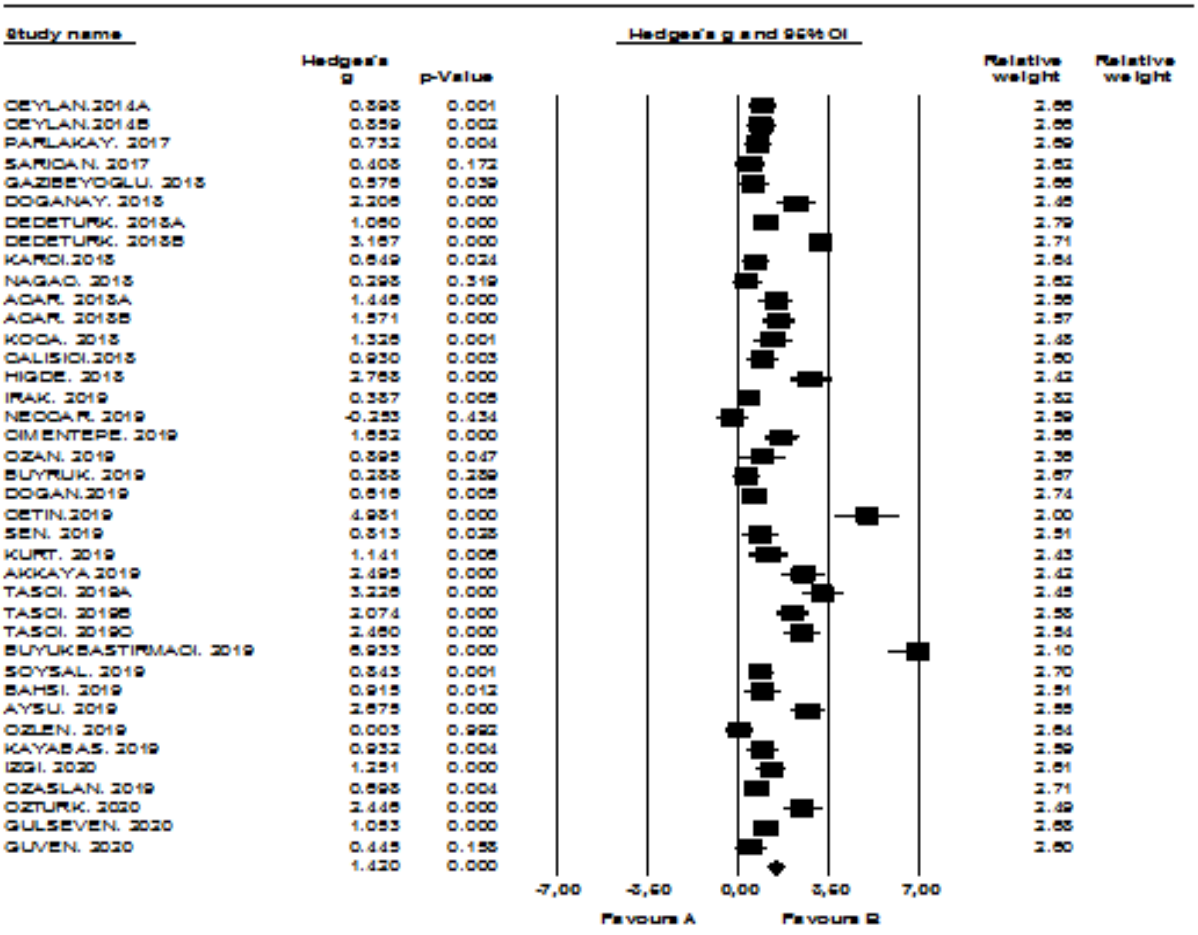

Figure 2. Forest Graph and Study Weights of Studies Related to the First Sub-Problem

When Figure 2 is examined, the parts represented as filled squares in the forest graph represent the individual effect sizes. The size of these squares is directly proportional to the number of samples. In addition, the horizontal lines passing through the squares represent the working ranges. The scale of the forest graph can be changed according to the effect size. Although the effect size value was generally concentrated between 0-1, the scale was kept wide in order to reveal the whole picture, since the effect size of a study was calculated as 6,933 (-7, +7). It is seen that the rhombus that expresses the overall effect size (1,420) in the forest graph is positive and a value greater than 1. This indicates that the STEM approach in science education has a large impact on academic achievement.

The Funnel Diagram of Studies Related to the First Sub-Problem (Publication Bias Graph) is given in Figure 3.

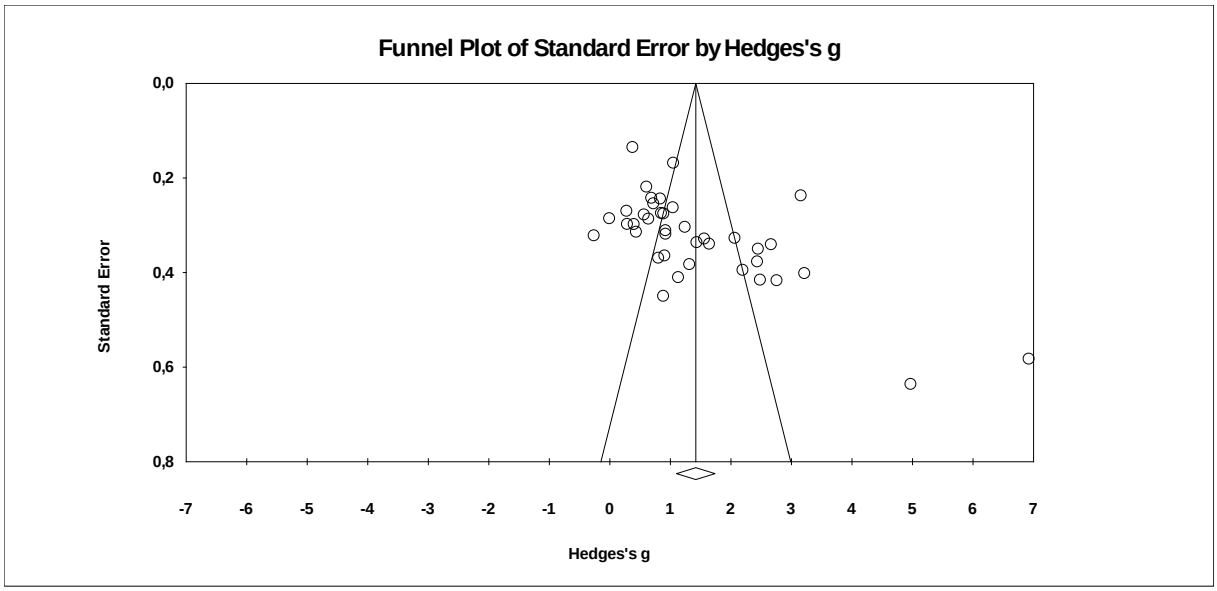

Figure 3. Funnel Diagram of Studies Related to the First Sub-Problem (Publication Bias Graph)

When the publication bias graph is examined, the effect sizes are seen on the horizontal axis, and values such as sample size or standard error are seen on the vertical axis. The line in the middle of the graph represents the overall effect value. Studies with a large sample size are generally clustered at the top of the graph and around the overall effect size. Studies with a small sample size are generally collected at the bottom of the funnel plot. It is expected that all individual studies will be scattered symmetrically and within the funnel lines to avoid publication bias. Studies scattered outside the funnel may cause publication bias. However, since Funnel graphs are generally evaluated subjectively, it is necessary to look at other publication bias statistics regarding publication bias (Dinçer, 2021).

Table 9. Classical Fail-Safe N Analysis of the First Sub-Problem

Rosenthal's Analysis of Protection Number	
Z value	26,151
p value	0,000
Alpha value	0,050
Z value for Alpha	1,959
N	39
Number of studies required to invalidate research	6905

When Table 9 is examined, the error protection number (fail safe N) obtained from the meta-analysis study was calculated as 6905 according to Rosenthal's method. This value is essentially the obtained p=0.000 significance value; It refers to the number of studies with an effect size value of "0" that should be included in the meta-analysis in order to increase the p>0.05 value, that is, to remove the significance. In this context, 6905 non-significant studies should be comprised in the meta-analysis in order to invalidate the findings and significance

obtained from the meta-analysis study made from the data of 39 studies. Since this number is quite high, it can be interpreted that the meta-analysis study carried out is reliable and the publication bias is low (Dinçer, 2021).

Orwin's fault protection number (Orwin's Fail-Safe N Analysis) data are given in Table 10.

Table 10. Orwin's Fail-Safe N Analysis of the First Sub-Problem

Orwin's Fault Protection Count Analysis	
Hedges' g in observed studies	1,112
Criterion for an insignificant Hedges's g	0,100
Average Hedges' g for Lost Studies	0,000
Number of Lost Runs required to bring Hedges' g to less than 0.1	395

According to Orwin's error protection number method, the average effect size obtained from the current study was calculated as 1.112, and in order to decrease the effect size value of the study to an insignificant value, it was necessary to include in the meta-analysis; There should be 395 studies with an effect size value of "0". Since it is very difficult to reach this number in the literature, it can be interpreted that the publication bias of the meta-analysis study conducted according to the findings obtained in this method is low and reliable (Dinçer, 2021).

Moderator Analysis Related to Grade Levels

In this section, it has been investigated whether there is an important difference between the effect sizes of the STEM approach in science education in terms of grade level on the academic achievement of students. In this context, the effects of the STEM approach in science education in terms of grade level in terms of students' academic achievement were determined as comparative effect sizes. Comparisons were grouped into 4th, 5th, 6th, 7th, and 8th graders. The individual and general effect sizes of the studies regarding the grade levels, the lower and upper limits of the 95% confidence interval, and the p values are given in Table 11.

Table 11. Individual and Overall Effect Sizes for Grade level Moderators, Lower and Upper Limits at 95% Confidence Interval, and p Values

Grade Level	***Study Code***	***Hedges's g***	***Lower Limit***	***Upper Limit***	***p-value***
Grade 4	ACAR, 2018A	1,446	0,784	2,107	0,000
Grade 4	ACAR, 2018B	1,571	0,924	2,218	0,000
Grade 4	OZTURK, 2020	2,446	1,705	3,188	0,000

Fixed		1,772	1,380	2,164	0,000
Random		1,798	1,208	2,388	0,000
Grade 5	PARLAKAY, 2017	0,732	0,231	1,233	0,004
Grade 5	KARCI,2018	0,649	0,085	1,213	0,024
Grade 5	IRAK, 2019	0,387	0,119	0,654	0,005
Grade 5	OZAN, 2019	0,895	0,010	1,779	0,047
Grade 5	GUVEN, 2020	0,445	-0,173	1,064	0,158
Fixed		0,507	0,307	0,707	0,000
Random		0,507	0,307	0,707	0,000
Grade 6	SARICAN, 2017	0,408	-0,178	0,995	0,172
Grade 6	DEDETURK, 2018A	1,060	0,727	1,392	0,000
Grade 6	DEDETURK, 2018B	3,167	2,699	3,635	0,000
Grade 6	NAGAC, 2018	0,298	-0,288	0,884	0,319
Grade 6	NECCAR, 2019	-0,253	-0,886	0,381	0,434
Grade 6	CIMENTEPE, 2019	1,652	0,984	2,320	0,000
Grade 6	CETIN,2019	4,981	3,732	6,230	0,000
Grade 6	KURT, 2019	1,141	0,334	1,947	0,006
Grade 6	AKKAYA 2019	2,495	1,678	3,312	0,000
Grade 6	AYSU, 2019	2,675	2,005	3,345	0,000
Fixed		1,457	1,275	1,640	0,000
Random		1,710	0,901	2,519	0,000
Grade 7	GAZIBEYOGLU, 2018	0,576	0,029	1,122	0,039
Grade 7	DOGANAY, 2018	2,206	1,429	2,982	0,000
Grade 7	KOCA, 2018	1,326	0,573	2,079	0,001
Grade 7	HIGDE, 2018	2,768	1,949	3,587	0,000
Grade 7	BUYRUK, 2019	0,288	-0,244	0,820	0,289
Grade 7	DOGAN,2019	0,616	0,185	1,048	0,005
Grade 7	SEN, 2019	0,813	0,087	1,539	0,028
Grade 7	BUYUKBASTIRMACI, 2019	6,933	5,789	8,078	0,000
Grade 7	KAYABAS, 2019	0,932	0,305	1,559	0,004
Grade 7	IZGI, 2020	1,251	0,653	1,849	0,000
Grade 7	OZASLAN, 2019	0,698	0,220	1,176	0,004
Grade 7	GULSEVEN, 2020	1,053	0,535	1,570	0,000
Fixed		1,084	0,910	1,257	0,000
Random		1,534	0,892	2,175	0,000
Grade 8	CEYLAN,2014A	0,898	0,355	1,440	0,001
Grade 8	CEYLAN,2014B	0,859	0,318	1,399	0,002
Grade 8	CALISICI,2018	0,930	0,318	1,542	0,003
Grade 8	TASCI, 2019A	3,226	2,436	4,015	0,000
Grade 8	TASCI, 2019B	2,074	1,430	2,718	0,000
Grade 8	TASCI, 2019C	2,460	1,771	3,148	0,000
Grade 8	SOYSAL, 2019	0,843	0,363	1,324	0,001
Grade 8	BAHSI, 2019	0,915	0,198	1,632	0,012
Grade 8	OZLEN, 2019	0,003	-0,560	0,565	0,992
Fixed		1,169	0,969	1,368	0,000

Random		1,330	0,739	1,921	0,000
Fixed	***Overall***	1,112	1,021	1,203	0,000
Random	***Overall***	0,806	0,637	0,976	0,000

When Table 11 is examined, the individual and general effect sizes of the grade level moderator were calculated. Actually, to make an interpretation, it is necessary to decide on the model selection by evaluating the heterogeneity test findings within the group (Dinçer, 2021). Table 12. includes heterogeneity test findings related to grade level.

Table 12. Heterogeneity Test Findings Related to Grade Level

Grade Level	***N***	***Standard Error***	***Heterogeneity***				***General Effect***	***%95 Confidence Interval***	
			Q-value	***df (Q)***	***P-value***	***I-squared***		***Lower Limit***	***Upper Limit***
Grade 4	3	0,200	4,484	2	0,106	55,399	1,772	1,380	2,164
Grade 5	5	0,102	2,573	4	0,632	0,000	0,507	0,307	0,707
Grade 6	10	0,093	162,560	9	0,000	94,464	1,457	1,275	1,640
Grade 7	12	0,088	145,011	11	0,000	92,414	1,084	0,910	1,257
Grade 8	9	0,102	68,724	8	0,000	88,359	1,169	0,969	1,368
Total WihtinFixed			383,352	34	0,000				
Total BetweenFixed			60,299	4	0,000				
Total BetweenMixed			32,237	4	0,000		0,806	0,637	0,976

When the heterogeneity test findings related to the grade level moderator of the study in Table 12 were analysed, firstly, the importance level of the within-group heterogeneity test in the fixed effects model was calculated as $p<0.05$. Apart from this, the statistical value of Q was found to be 383,352 and the df degree of freedom was 34. The critical value of the $\chi 2$ table at the df=34 level and at the 95% importance level is between 43,773 and 49,802 values. It was monitored that the statistical value of Q calculated in the heterogeneity test ($p<0.05$) was higher than the critical value determined in the chi-square distribution at 34 degrees of freedom, and it is significant since $p<0.05$. In the light of this result, it is deduced that the studies have the same widespread effect within themselves. However, studies can be interpreted as heterogeneous because they have a higher distribution than expected. In addition, the p value was calculated according to the betweengroup heterogeneity test according to the mixed effects model. The importance level of the test was calculated as $p=0.000$. In addition, when the Q statistical value of the study was examined, it was calculated as 32,237 and the degree of freedom was 4. The critical value of the $\chi 2$ table at the 95% significance level is 9,488. It was observed that the calculated Q statistical value was 32,237 ($p<0.05$), exceeding the critical value determined in the chi-square distribution at 4 degrees of freedom. According to both models, there is a statistically important difference

between the subgroups. As a matter of fact, since the source of the variance between the groups is investigated, it is necessary to report according to the mixed effects model (Dinçer, 2021). In this case, it was concluded that the academic achievement effect sizes of the STEM approach in Science Education made an important difference according to the grade level moderator created and the academic achievement of the studies conducted at the 4th grade level was higher than the other grade levels. In Table 13, the overall effect sizes for the grade level moderator are given.

Table 13. Random Effects Model General Effect Sizes Related to Grade Level Moderator

Grade Level	*Number of Study*	*Effect Size*	*Lower Limit*	*Upper Limit*	*p-value*
Grade 4	3	1,798	1,208	2,388	0,000
Grade 5	5	0,507	0,307	0,707	0,000
Grade 6	10	1,710	0,901	2,519	0,000
Grade 7	12	1,534	0,892	2,175	0,000
Grade 8	9	1,330	0,739	1,921	0,000
General		0,806	0,637	0,976	0,000

According to the Random Effects Model in the moderator of the grade level, the effect size of the 4th grade level has the largest effect size and its value was calculated as 1,798. It is followed by the Grade 6 level with an effect size of 1,710. This value is followed by the effect size of the 7th grade level of 1,534. Afterwards, 8th and 5th grade levels come with effect sizes of 1,330 and 0.507. According to the scale of Cohen (1988), 4th, 6th, 7th, and 8th grade level effect size values express a large level of effect; Grade 5 level effect size corresponds to medium effect size according to the same scale. According to the Thalheimer and Cook (2002) scale, the effect size of the 5th grade level is medium and the remaining grade levels indicate a very large level.

In terms of grade levels, the individual effect sizes of the STEM approach in science education on academic achievement are given in Figure 4. effect sizes are positive at all grade levels, except for one study at grade 6.

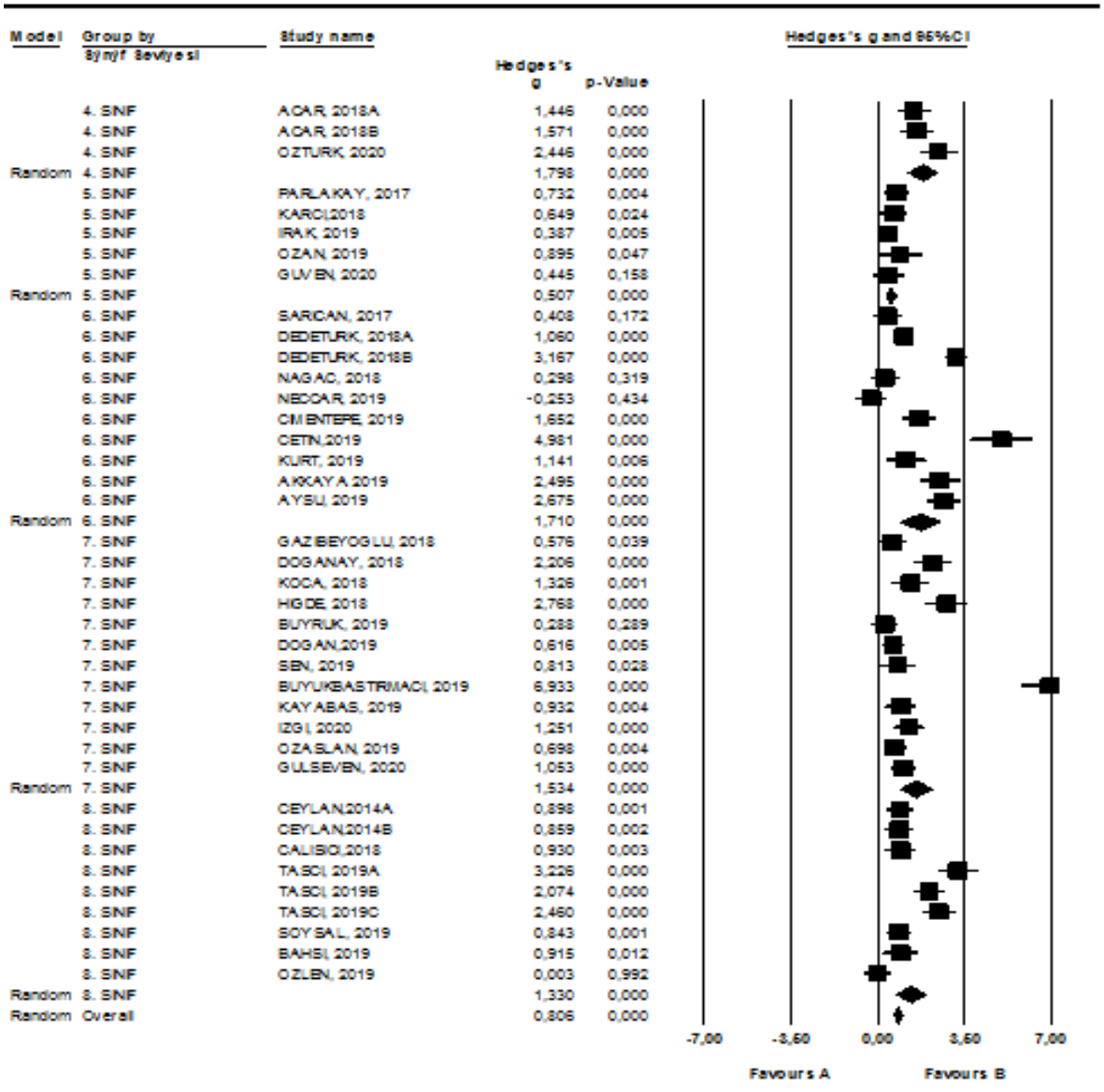

Figure 4. Distribution of Effect Sizes and Forest Graph for Grade Level Moderator

Discussion

In this section, the descriptive statistical findings of the study and the findings related to the sub-problems are discussed and interpreted.

In order to determine the effect of the STEM approach in Science Education on the academic achievement of students, a total of 147 studies, 130 master's and 17 doctoral studies, were carried out between 2010-2020. However, a total of 34 studies, including 31 master's and 3 doctoral studies, that met the inclusion criteria were included in the research. 23.85% of master's theses and 17.65% of doctoral theses; 41.50% of the theses reached in total were included in the meta-analysis. When the rates of inclusion of the studies reached in the meta-analysis were examined, it was seen that both master's and doctoral theses were included in

the study at similar rates in total. However, it has emerged that quantitative studies at the doctoral level are insufficient and it is necessary to conduct studies at this level. When the grade levels of the studies included in the research are examined, it is seen that the research was conducted at the 7th grade level at most. When the Science Curriculum is examined, it is thought that the existence of many units and sub-topics in different learning areas suitable for organizing STEM activities in the 7th grade Science Curriculum may cause the studies to be concentrated at this grade level.

Considering the rates of these studies, it is striking that the rate of master's theses made within the scope of academic achievement variable is 91.17%. It is of great importance in terms of demonstrating the effectiveness of the STEM approach in science education on academic achievement, as the large number of qualified data to be included in the research in meta-analysis studies will ensure that the overall effect size obtained as a result of the analysis is more accurate. In this regard, the need to conduct doctoral-level studies on the STEM approach has emerged. In addition, among 34 studies within the scope of the research; In Ceylan (2014), Doğanay (2018), Acar (2018) studies, two different experimental and control groups; As Taşçı (2019) applied three different achievement tests, a total of 39 data were obtained. It is striking that mostly a single experimental and control group and a achievement test in one area were used in the studies. In addition, it is seen that more than half of the 34 theses examining the achievement variable were studied in 2019. This means that the interest in STEM education has increased recently and the Science, Engineering and Entrepreneurship Practices in the Science Curriculum, which was renewed in 2018 and revised in 2019, are thought to be extremely effective. At the same time, when the sample numbers and grade levels of the theses included in the research were investigated, it was observed that the studies consisting of 39 data from 34 studies consisted of a total of 1962 people and corresponded to 50 students on average. Since the studies included in the meta-analysis are experimental studies carried out with a quantitative approach, the sample size is expected to be 50 students on average; it is thought that they were chosen as the experimental and control groups during the application was effective in the emergence of this situation. It is seen that most of the studies included in the research consisted of 6th and 7th grade students. It is thought that the renewed Science Curriculum was effective in the emergence of this situation.

When the findings related to the effect sizes were examined, 38 positive studies and 1 negative study were found out of 39 data in the 95% confidence interval. It is expected that studies with a positive effect size will be more numerous than studies with a negative effect.

The fact that a study has a negative effect size shows that the study is on behalf of the control group (Wolf, 1986). It is thought that this situation may be caused by operator error. Apart from this, the effect size of the remaining 38 studies is on behalf of the experimental group. The study with the largest effect size in individual studies belongs to the study of Büyükbastırmacı (2019), while the smallest effect belongs to the study of Neccar (2019). While 27 studies among 39 data obtained from 34 studies had large effect size; 5 studies had a medium effect size, 5 studies had a small effect size, and finally 2 studies had a negligible effect.

The effect sizes of the individual studies were first combined according to the fixed effects model with the help of the CMA program, and the overall effect size was computed as 1.112 at the 95% confidence interval. As a matter of fact, as a result of the heterogeneity test, it was determined that the Q value was higher than the critical value in the X^2 table, so the studies had a heterogeneous structure. In this context, the calculations were made according to the random effects model. As a result of the analyses made according to this model, the overall effect size was calculated as 1,420, and based on this finding, it can be said that the STEM approach in science education has a positive and large effect on the academic achievement of students.

It is stated that 6905 studies are needed to remove the significance level of 39 studies combined with the meta-analysis method (Rosenthal Method), and it is impossible to reach this number; in addition, it can be said that the findings obtained from the analysis results are reliable as the general effect size is large and at least 395 studies are needed to reduce this effect to an insignificant value like 0.100 (Orwin Method).

In his meta-analysis study, Saraç (2018) stated that 25 of 27 individual data on the effect of STEM education applications in science and mathematics courses on the academic achievement of students had a positive effect and 2 had a negative effect. In addition, it was concluded that the overall effect level was 0.442 and moderate, and that the applied STEM education practices had a positive effect on the academic achievement of the students. Yücelyiğit and Toker's (2020) meta-analysis study on Early Childhood Education STEM studies stated that all 12 individual data had a positive effect on the extent to which STEM activities applied to preschool children affect learning and language development, and expressed the overall effect level. It was calculated as 0.556. As a result of the research in question, it has been concluded that this effect has a moderate effect and that the STEM activities applied have a positive effect on the language development and learning of the

students. In the study of Ayverdi and Öz Aydın (2020), the effect of STEM education on academic achievement was investigated by comparing STEM researches conducted in our country and abroad. In the study, 38 studies were examined, and it was revealed that the individual effect sizes calculated in the data analyzed from the studies conducted in our country were mostly medium and large. The effect sizes of studies conducted abroad were generally calculated as small and large. It is seen that these studies are relatively consistent with the findings on the effect of the STEM approach in science education on academic achievement.

As a result of the literature review, the number of meta-analysis studies applied with the STEM approach is negligible. However, there are individual studies that will show the positive effect of the STEM approach in science education on the academic achievement of students (Ceylan, 2014; Parlakay, 2017; Sarıcan, 2017; Gazibeyoğlu, 2018; Doğanay, 2018; Dedetürk, 2018; Karcı, 2018; Acar, 2018; Koca, 2018; Çalışıcı, 2018; Hiğde, 2018; Irak, 2019; Çimentepe, 2019; Ozan, 2019; Buyruk, 2019; Doğan, 2019; Çetin, 2019; Şen, 2019; Kurt, 2019; Akkaya, 2019; Taşçı, 2019; Büyükbastırmacı, 2019; Soysal, 2019; Bahşi, 2019; Aysu, 2019; Özlen, 2019; Kayabaş, 2019; İzgi, 2020; Özaslan, 2019; Öztürk, 2020; Gülseven, 2020; Güven, 2020).

The studies in the research, 3 of them were studied at the 4th grade level, 5 of them at the 5th grade level, 10 of them at the 6th grade level, 12 of them at the 7th grade level and 9 of them at the 8th grade level. According to the heterogeneity test results, it is heterogeneous within and between groups. The effectiveness of the STEM approach in science education differs according to the grade level. The highest impact value is at the 4th grade level, and the lowest impact value is at the 5th grade level. However, when the effect size values are examined according to the Cohen (1988) scale, at the 4th, 6th, 7th and 8th grade levels; it is seen that it is moderately effective at the 5th grade level. This situation is thought to be due to the fact that the general effect sizes of the studies at the other grade level are higher compared to the 5th grade level in terms of grade level.

Results and Suggestions

When the effect size values of the studies included in the meta-analysis are classified, the effect size value is at least moderate in most of the studies. In addition, the direction of the effect size of the majority of the studies included in the meta-analysis is positive. The effect size of the STEM approach in science education on academic achievement is large, significant

and positive. Therefore, it can be said that the STEM approach in science education is quite effective in increasing the academic achievement of students.

When the effect of STEM approach in science education on academic achievement according to grade level was examined, it was concluded that it had a positive effect on all grade levels and that there was a statistically important difference between grade levels in the heterogeneity test. Considering the effect size values according to the grade levels, it was seen that the lowest effect size value was at the 5th grade level, and the highest effect size value was at the 4th grade level. It has been concluded that while the effect of STEM approach in science education on the academic achievement of the 5th grade students is moderate, it has a wide effect on all other grade levels.

In our country and abroad, there have been many studies examining the STEM approach on students, pre-service teachers and teachers recently. In these studies, the effects of STEM approach on variables such as academic achievement, attitude towards science course, scientific process skills, motivation, conceptual understanding, career interest, and permanence were examined. In addition, there are also studies in which STEM education is examined according to independent variables such as gender, age, education level, grade level and course type and different results are obtained. When the results in the literature were examined, a meta-analysis was needed to gather the studies examining the effect of the STEM approach on existing variables under a single roof and to reveal the trends in this research area. In this respect, this study, which examines the effect of STEM approach on academic achievement in science education, is thought to shed light on future studies.

In the light of the findings obtained as a result of the analyses made within the scope of the research, some suggestions were made for researchers and practice.

According to the results of the research, it has been seen that the STEM approach in science education has a positive and large effect on the academic achievement of the students. Therefore, it can be recommended that the STEM approach be widely used at all levels of education. In this direction, teachers should be made aware of the STEM approach and in-service training should be given in this direction. As a result, it is thought that the STEM approach will increase the quality of education and training.

In meta-analysis studies, as the quantity increases, that is, when more publications are reached, the quality also increases in direct proportion. As a matter of fact, the large number of publications is important in terms of giving more reliable results of the research. It has been observed that the working history of the STEM approach in our country is not very old; there

has been an increase in the number of studies conducted in recent years. Increasing studies in this direction will reveal the effect of the STEM approach on academic achievement in a more generalizable and clear manner.

Researchers have difficulty in accessing the theses that are not accessible in the National Thesis Center of the Council of Higher Education. The solution of this problem may be effective in the emergence of more qualified studies.

The fact that most of the theses included in the research are master's theses reveals the lack of studies done at the doctoral level. In the future, the number of studies at the doctoral level may be increased. In addition, cross-country comparisons can be made by researchers.

In the studies included in the meta-analysis, it was observed that the researchers mostly conducted experimental studies at the primary school level. For these reasons, the number of studies carried out in other education levels can be increased.

The characteristics of the studies to be included in the meta-analysis and the fact that the statistics needed to compute the effect size are not given enough or in accordance with the meta-analysis affects the quality of the meta-analysis studies. As a matter of fact, the lack of a standard in the presentation of the data in the studies complicates the work of the researchers. In this context, it is recommended that researchers show sensitivity to include both descriptive and statistical data in a more systematic and complete manner in their studies.

In the current study, only the studies conducted for the science course were included in the research. Since the STEM approach is an approach that is directly related to many disciplines, meta-analysis can be carried out in many areas.

Fen Eğitiminde STEM Yaklaşımının Akademik Başarıya Etkisi : Bir Meta-Analiz Çalışması

Özet:
Bu araştırmada Türkiye'de fen eğitiminde STEM yaklaşımının öğrencilerin akademik başarıları üzerindeki etkisini incelemek amacıyla meta analiz çalışması yapılmıştır. Yapılan meta analiz çalışmasında belirlenen ölçütlere uygun olarak araştırma kapsamına alınan çalışmalar Yüksek Lisans ve Doktora düzeyinde olup bu çalışmalar Yüksek Öğretim Kurulu Başkanlığı Ulusal Tez Merkezi veri tabanından alınmıştır. Araştırmada, 2010-2020 yılları arasında gerçekleştirilmiş, toplam 147 çalışma incelenmiş ve dâhil edilme kriterlerine uygun olan 31 Yüksek Lisans ve 3 Doktora tez çalışması meta analiz kapsamına alınmıştır. Toplam 34 adet çalışmanın örneklemini 4., 5., 6., 7. ve 8. sınıf seviyesindeki toplam 1962 öğrenci oluşturmaktadır. Analizler Compreh ensive Meta Analysis V2 istatistik programı yardımıyla yapılmıştır. Çalışmalar analiz edilip birleştirildiğinde yapının heterojen olmasından dolayı rastgele etkiler modeli kullanılmıştır. Araştırma sonucunda, fen eğitiminde STEM yaklaşımının öğrencilerin akademik başarısına etki büyüklüğü 1.420 olarak hesaplanmıştır. Bu değer, yapılan sınıflandırmaya göre akademik başarı değişkeni açısından geniş düzeyde bir etki büyüklüğüdür. Bu bağlamda fen eğitiminde STEM yaklaşımı öğrencilerin akademik başarısını arttırmada olumlu yönde ve geniş düzeyde bir etkiye sahip olduğu sonucuna ulaşılmıştır. Akademik başarıya olan etki büyüklüğü sınıf seviyesine göre farklılaşmış olup en yüksek etki 4. sınıf seviyesindeki çalışmalarda gözlenmiştir.
Anahtar Kelimeler: STEM, fen bilimleri, akademik başarı, meta analiz.

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