Education Quarterly Reviews

Taşdemir, F. (2022). Examination of the Effect of Stem Education on Academic Achievement: A Meta-Analysis Study. *Education Quarterly Reviews*, 5(2), 282-298.

ISSN 2621-5799

DOI: 10.31014/aior.1993.05.02.489

The online version of this article can be found at:
https://www.asianinstituteofresearch.org/

Published by:
The Asian Institute of Research

The Asian Institute of Research *Education Quarterly Reviews* is a peer-reviewed International Journal. The journal covers scholarly articles in the fields of education, linguistics, literature, educational theory, research, and methodologies, curriculum, elementary and secondary education, higher education, foreign language education, teaching and learning, teacher education, education of special groups, and other fields of study related to education. As the journal is Open Access, it ensures high visibility and the increase of citations for all research articles published. The *Education Quarterly Reviews* aims to facilitate scholarly work on recent theoretical and practical aspects of education.

ASIAN INSTITUTE OF RESEARCH
Connecting Scholars Worldwide

ASIAN INSTITUTE OF RESEARCH
Connecting Scholars Worldwide

The Asian Institute of Research
Education Quarterly Reviews
Vol.5, No.2, 2022: 282-298
ISSN 2621-5799

DOI: 10.31014/aior.1993.05.02.489

Examination of the Effect of Stem Education on Academic Achievement: A Meta-Analysis Study

Fazilet Taşdemir[1]

[1] Faculty of Education, Department of Educational Sciences, Recep Tayyip Erdoğan University, Rize, Turkey

Correspondence: Fazilet Taşdemir, Faculty of Education, Department of Educational Sciences, Recep Tayyip Erdoğan University, Rize, Turkey. E-mail: fazilet.tasdemir@erdogan.edu.tr

Abstract
Countries with well-trained and qualified labor force today make a significant difference with other countries in areas such as economy, education and industry. One of the important reasons for this difference is that these countries have made innovations in the fields of science, technology and education policies as well as economy. STEM, which is composed of the abbreviations of the first letters of the words Science, Technology, Engineering and Mathematics, is an interdisciplinary approach. The aim of this study is to gather the experimental dissertations examining the effect of STEM education on students' academic achievements in order to determine the effect of STEM education on academic success and synthesize the study findings. The research was conducted in a screening model. In the study, as there is heterogeneity among the publications included among the scope of the meta-analysis, the size of the impact was calculated utilizing the random effects model. The dissertations examined within the scope of this study were accessed from the Higher Education Institution (HEI) National Study Search System databases using the keywords STEM, academic achievement and experimental model. In this study, dissertations were examined by taking a certain time criterion. A total of 26 dissertations (19 postgraduates and 7 doctoral) examining the effect of STEM education, which is the post-test scores of the experimental and control groups conducted in 2018-2020, on academic achievement were accessed from the database. It was concluded in the study that STEM education has a positive effect on the academic achievements of students.

Keywords: Academic Achievement, Education, Education Dissertation, Meta-Analysis, STEM

1. Introduction

1.1 Introduce the Problem

Countries seek qualified labor force to advance in industry and economically. Considering that individuals equipped with 21st-century skills will play a role in development, there is additionally a search for different education approaches in the education of individuals. It is this pursuit that has led to the emergence of STEM education (White, 2014). STEM, which is composed of the abbreviations of the first letters of the words Science, Technology, Engineering and Mathematics, is an interdisciplinary approach. The STEM approach allows students to develop critical thinking, creativity, social interaction skills, also leading to a change in their academic

achievements (Roberts, 2012). Academic achievement is identified not based on student performance in class, but on the social skills exhibited by students both during school and out-of-school times (Grund & Grote, 2004). STEM education, which forms the integrity of knowledge with the power it gets from the overlapping of more than one discipline, helps students gain the skills that can meet their everyday needs with the knowledge they attain as a result of the necessary research carried out to reach the information they require (Corlu, 2012; Yıldırım, 2016). Students who receive STEM education grow as problem-solving, innovative, self-confident, analytical, science and technology-literate individuals (Morrison, 2006).

American politicians have identified STEM education since 2001 as a key that will revive the economy, and thus popularizing STEM education became a general policy (Lacey & Wright, 2009). It is stated that students, who gain an innovative perception through STEM education, have a holistic approach that allows them to understand the world as a whole rather than parts (Israel, Maynard & Williamson, 2013; Lantz, 2009). STEM activities around the world are implemented in terms of context and content. STEM activities are planned to support the teaching of a discipline in terms of a context, while in terms of content, activities are planned considering the disciplines that form STEM as a single discipline. (Roehring, Moore, Wang & Park, 2012). STEM education and STEM labor force are increasingly emphasized in many countries around the world that aim to advance in technology and innovation. Countries include STEM in their education systems. STEM started to be implemented in many developed countries from primary schools to secondary schools and universities. Studies show that the STEM education provided at primary and secondary schools reaches the highest level at universities. It can be concluded that STEM education contributes greatly to students' choice of profession (Gonzalez & Kuenzi, 2012).

The STEM education approach, which is seen to be shaped by economic reasons, has been applied to students since the 21st century. In this century, STEM education approach has been deemed necessary for students to acquire the necessary skills and direct them to STEM professional fields (Bybee, 2010; Sanders, 2009). For this reason, it is seen that the STEM education approach is important for the sustainability of economic growth, both for policy makers and students.

The Organization for Economic Cooperation and Development (OECD) compared student achievement in mathematics with the Program for International Student Assessment (PISA), which evaluates the knowledge and skills of 15-year-old students in three-year terms. The leading countries in the ranking of success were determined as China, Singapore, Taiwan, Korea, Finland and Switzerland. In these countries, it has been seen that importance is given to STEM workshops and activities. Health vocational high schools, agriculture, environment and related fields are included in the official scope of STEM in Australia (Marginson, Tytler, Freeman & Roberts, 2013).

China is leading the innovations in the STEM field. Innovation studies in these countries (Africa, Latin America, developing Asian countries, the Middle East) called the Global South are important for global development. It is seen that global information inventions and STEM products are increasing in Asia, and there has been an increase in the number of participation in patent applications in STEM fields, especially in the Global South countries in the last 40 years (Cortes-Sanchez, Carbonell, & Guix, 2020). With the new programs prepared, Russia first focused on eliminating the deficiencies in education by strengthening the education of institutes in universities. Regarding STEM education, they aimed to improve the quality of engineering programs, improve mathematics education, and develop the engineering, medicine and science programs of higher education institutes under the leadership of universities (Smolentseva, 2015). In Turkey, when the expected results could not be achieved in exams such as TIMSS and PISA, the Ministry of National Education included objectives for strengthening STEM in its 2015-2019 Strategic Plan. In order to bring these results to the expected level, STEM education in Turkey has been considered as an important approach that should be given priority (MNE, 2016).

In the plan published in 2014 for STEM education in the Finnish education system, it is aimed to establish working groups to increase the interest and abilities of children and young people in STEM disciplines, and to serve as cultural and educational leaders of these groups. Latvia has a strategic plan for a STEM education aimed at increasing students' competence in mathematics and science. In order to achieve this goal, it is aimed to use digital learning tools that will be developed for use in primary and secondary school education programs. Poland renewed its curricula and focused on mathematics skills in order to improve the quality of education at the secondary school

level in the 2014-2015 academic year. In the USA, STEM education is considered very important for the country's economy, and many STEM Centers have been established in universities and schools throughout the country (Kearney, 2016).

In STEM education applications, students are presented with knowledge-based life problems including real-world problems, and students are asked to develop solutions for these problems in the process (English, 2017; Shaughnessy, 2013). In this process, lessons are generally conducted by using project-based learning, 5E model and engineering design cycle techniques (Capraro, 2013; English & King, 2015). It is possible to say that the applications generally take place within the scope of the science course in the curriculum (English, 2016).

In the study by Suratno, Wahono, Chang, Retnowati, & Yushard (2020), the factors affecting the quality of education from students' problem-solving abilities and academic learning achievements were examined. It has been observed that there is a positive relationship between students' problem-solving skills and academic learning achievements in favor of STEM education. Similar studies on this topic are summarized below:

Ercan (2014) examined the effect of Design-Based Science Education on 7th- grade students' academic achievement levels aimed at the force and motion unit, their decision-making skills, level of knowledge aimed at the Engineering discipline, their skills on applying the Engineering Design Process, and students' views regarding engineering. The study revealed that Design-Based Science Education developed students' academic achievements, their decision-making skills and level of interest in the Engineering discipline, that they improved in terms of determining the most appropriate solution suggestion for the problem situation, and that their competences developed at the prototype making and testing stage. Dedeturk (2018) conducted studies focusing on STEM education, and in his study, he examined whether the shortcomings regarding sound could be fixed, while also examining the change in the levels of achievement. As a result of the research, he determined that STEM education has a positive impact on increasing students' achievement levels. Gazibeyoglu (2018) examined the effect of STEM practices on 7th-grade students' achievements and attitudes in the force and energy unit. It has been determined that STEM practices influence academic achievement and attitude. Kuru & Akman (2007) examined the scientific process skills of children continuing to study at preschool institutions in terms of various variables. As a result of the study, while they reached the conclusion that there is a significant correlation between the variables of the children's age, the type of school they are continuing to attend, whether they received pre-school education, they also concluded that there is no significant correlation between teachers' period of service in the profession and the duration of the science activities that carry out, as well as children's scientific process skills. Tseng, Chang, Lou & Chen (2013) examined project-based learning activities integrated with STEM Education on 30 students studying in the first grade at the Institute of Technology in Taiwan. It has been observed that students' approaches to engineering have changed significantly. Most students have emphasized the importance of Stem in the disciplines of Science and Engineering. It has been observed that project-based learning activities integrated with STEM are important in terms of influencing student behavior in order to create important learning and career choices in the future. Duygu (2018) examined the effect of simulation-based STEM education in terms of students' scientific process skills and STEM awareness. As a result of the study, it is stated that the simulation program ensures a positive effect in terms of the engineering component in the STEM field, and achieves superiority with respect to experiment and product development. Cakar (2019), on the other hand, examined the impact of the educational activities implemented on digital platforms in terms of the Physics course with the reverse teaching model on students' academic achievements, their course-related performance levels, their problem-solving skills and attitudes towards the physics course. As a result of the study, the academic achievements of students in the experimental group, their physics performance and attitudes towards the course were found to differ significantly compared the control group students, while there was no significant difference between their problem-solving skills.

It has been observed that studies examining the relationship between academic achievement, academic skills and STEM have been made in the literature. However, no studies were found in which the findings of these studies and dissertations were examined together and the results were mentioned.

It has become necessary to study dissertations that reveal the impact of STEM education and its applications on academic achievement and to present the overall impact of its results. In this study, it is aimed to examine the effect of STEM education on students' academic achievements. In accordance with this general purpose, the answers to the following questions were sought:

1) Is there heterogeneity among the dissertations on STEM published using the experimental model?
2) Which group is in favor of the average effect size value in the dissertations on STEM published using the experimental model?
3) Is there publication bias among STEM dissertations published using the experimental model?

This study is important as it provides the opportunity to gather and synthesize studies that present different results regarding STEM education, and compare them with meta-analysis studies conducted in different fields.

2. Method

2.1 Research Design

The research was conducted in a screening model. The main purpose of using the screening model is to examine the existing situation in detail according to the independent variables. A screening model is used in studies aimed at depicting a situation that has happened in the past or still exists in its current state (Karasar, 2014).

Experimental studies examining the effect of STEM education on academic success were accessed within the scope of this study to perform their meta-analysis. Meta-analysis is the ability to combine the results of many independent studies conducted on a particular topic and perform a statistical analysis of the results (Akgöz, Ercan & Kan, 2004). Meta-analysis, a set of statistical techniques for synthesizing the results of multiple studies (Higgins & Green, 2011), is used in a systematic review when the guiding research question focuses on a quantitative summary of study results. Studies in relation to examining publications in a specific field using meta-analysis are beneficial in the processes ranging from the planning of academic studies to their management (Betts & Lansley, 1993).

2.2 Study Group

The dissertations examined within the scope of this study were accessed from the Higher Education Institution (HEI) National Study Search System databases using the keywords STEM, academic achievement and experimental model. In this study, dissertations were examined by taking a certain time criterion. 19 postgraduates and 7 doctoral dissertations, examining the effect of STEM education, which is the post-test scores of the experimental and control groups conducted in 2018-2020, on academic achievement were accessed from the database. While examining the dissertations, attention was paid to the fact that they were made in education faculties. First, dissertations related to STEM and academic achievement are listed. In addition, attention was paid to the study of the difference between the results before and after the test compared to the control group in the dissertations.

Table 1: Published dissertations on STEM and academic achievement

	Universities with dissertations written on STEM and academic success	Publication year	Publication type
1	Erciyes University	2018	Doctorate
2	19 Mayıs University	2018	Doctorate
3	Adnan Menderes University	2018	Postgraduate
4	Karamanoglu Mehmetbey University	2018	Postgraduate
5	Sinop University	2018	Postgraduate
6	19 Mayıs University	2019	Postgraduate
7	Bartın University	2019	Postgraduate
8	Gazi University	2019	Postgraduate

9	Fırat University	2019	Postgraduate
10	Gazi University	2019	Postgraduate
11	Gazi University	2019	Doctorate
12	Manisa University	2019	Doctorate
13	Marmara University	2019	Postgraduate
14	Muğla Sıtkı Koçman University	2019	Doctorate
15	Pamukkale University	2019	Postgraduate
16	Erciyes University	2020	Postgraduate
17	Atatürk University	2019	Postgraduate
18	Cukurova University	2019	Doctorate
19	Akdeniz University	2019	Postgraduate
20	Fırat University	2019	Doctorate
21	Kırşehir Ahi Evran University	2019	Postgraduate
22	Van Yüzüncü Yıl University	2020	Doctorate
23	Yıldız Teknik University	2020	Postgraduate
24	Marmara University	2019	Postgraduate
25	Erciyes University	2019	Postgraduate
26	Istanbul University	2020	Doctorate

In each dissertation, those in the experimental group were examined based on STEM education, while those in the control group were examined according to the application of non-STEM education methods and techniques. In addition, attention was paid to taking final test measurements from the experimental and control groups. Furthermore, when transferring the studies to the (CMA) program, for publications in the experimental and control groups, data was entered under the titles sample size, the standard deviations of arithmetic averages. For the other studies, which were examined for effect over a single group only, data continued to be entered in accordance with the pre-test and final test averages, and the t-test value.

2.3 Data Analysis

A master key has been developed in order to determine the dissertations analyzed. The year the dissertations were conducted and their type, sample size, the arithmetic averages of the study findings and their standard deviations and t-test results were entered into this key. The information obtained according to these criteria was entered into the CMA program. The impact of the dissertations was determined in efforts to reach the size of common impact. Two effect models are used in the body of literature. One of the fixed and random effects models is preferred. The assumption of the fixed effect model is that there is only one real impact size for all dissertations in the meta-analysis. In the random impacts model, studies with small sample size are weighted in accordance with the sample size. As there is heterogeneity among the dissertations examined within the scope of the study, the random effects model was used to examine the effect size. This model focuses on high heterogeneity among dissertations in all studies.

Stages of Application of Meta-analysis

Meta-analysis is a subset of systematic reviews. A systematic review attempts to collate empirical evidence that fitspre-specifiedd eligibility criteria to answer a specific research question. The conduct of a meta-analysis, in general, includes the following stages (Saunders & Trapp, 1994);

- Defining the problem,
- Including individual studies in the meta-analysis determining the criteria,
- Coding and classifying each study according to the characteristics associated with its meta-analysis,
- Combining the findings of individual studies,
- Establishing the relationship of findings combined with the characteristics of meta-analysis,
- Reporting the findings of the meta-analysis.

The framework of this study was created by taking into account the necessary stages for meta-analysis. After the research purpose and sub-objectives were defined, the dissertations to be included in the meta-analysis were determined. In the examination of the dissertations related to the concepts of STEM and academic success between the years 2018-2021, it was seen that the most experimental model was conducted in the years 2018-2020. Thus, the time code of the study has determined as 2018-2020. In the dissertations examined, another meta-analysis code was created according to the pretest-posttest or posttest applied according to the STEM education status in the experimental and control groups. The situation of conducting the analyzes applied in the dissertations in paired and independent groups is also considered as a code. In the dissertations, group averages, standard deviations, variances, effect sizes were also entered as codes.

3. Results

3.1 Statistics and Data Analysis

The data of the independent and paired groups of dissertations conducted using the experimental research pattern were examined one by one. In the meta-analysis, the results have obtained using the random effects model. In this study, it was determined as an important criterion that the dissertations examined in the meta-analysis must have posttest measurements. In the heterogeneity analysis, the arithmetic means, sample sizes, and standard deviation values of the experimental group and control group in each dissertation were included in the analysis. In order to examine the dissertations that reveal the impact of STEM education and its applications on academic success and to present the overall effect of its results, the heterogeneity of dissertations written with experimental model was first examined.

In the research, the average effect size value in dissertations on STEM is examined in separate tables for dependent and independent groups. In the analysis, the dissertations were examined according to the values obtained from the arithmetic mean, degrees of freedom and t values. In the research, publication bias was also examined among the dissertations on STEM published using the experimental model.

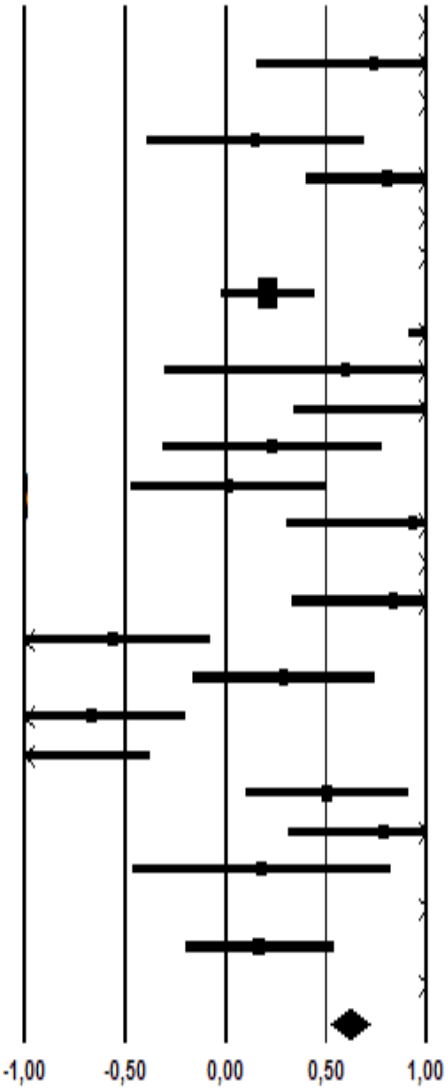
1. Is there heterogeneity among the dissertations on STEM published using the experimental model?

One other important statistic used in choosing either the fixed or random effects model is the Q statistic. In the analysis of the Q statistic, the hypothesis is tested in accordance with whether all the studies share the general effect. As a result of the analysis, if the importance value is below the critical value, not all studies share the existing effect (Borenstein, Hedges, Higgins & Rothstein, 2009; Hedges & Olkin, 1985). In this case, there is heterogeneity among the dissertations examined. The concept of heterogeneity is a concept associated with the magnitude and degree of variability between studies. The more variable the estimates between studies are, the higher the heterogeneity. In such a situation, it is necessary to investigate the source of heterogeneity.

I^2 statistics, on the other hand, provides information about the rate of this heterogeneity. The Q statistic calculated in this study has shown there is heterogeneity among the dissertations. The publication bias of the dissertations included within the scope of the study is examined using the funnel plot. In cases where there is no publication bias, the funnel plot is expected to present symmetry. The chart of studies clustering on the internal and end sections shows it contributes highly to the effect size. The magnitude (dot) of the effect value obtained from each dissertation is indicated on a line. The diamond symbol is the average effect size value. The size of the black boxes indicates the weight of the studies. The two ends of the lines are a 95% confidence interval.

Table 2: Forest graph regarding the effect of STEM education on academic achievement

Meta Analysis		Statistics for each study				
Study Name	Hedges' s g	Standard error	Variance	Z-Value	p-Value	Hedges's g and 95% CI
1	2.004	0.212	0.045	9.463	0.000	
2	0.740	0.300	0.090	2.466	0.014	
3	2.768	0.418	0.175	6.622	0.000	
4	0.149	0.277	0.077	0.537	0.591	
5	0.802	0.206	0.042	3.897	0.000	
6	2.398	0.336	0.113	7.145	0.000	
7	8.570	1.053	1.108	8.141	0.000	
8	0.209	0.120	0.014	1.751	0.000	
9	1.304	0.203	0.041	6.441	0.000	
10	0.599	0.460	0.212	1.303	0.193	
11	1.141	0.411	0.169	2.772	0.006	
12	0.231	0.279	0.078	0.828	0.408	
13	0.013	0.247	0.061	0.054	0.957	
14	0.932	0.320	0.102	2.915	0.004	
15	2.192	0.334	0.112	6.559	0.000	
16	0.836	0.258	0.066	3.242	0.001	
17	-0.561	0.248	0.062	-2.259	0.024	
18	0.290	0.230	0.053	1.259	0.208	
19	-0.665	0.237	0.056	-2.808	0.005	
20	-1.011	0.322	0.104	-3.137	0.002	
21	0.503	0.206	0.043	2.439	0.015	
22	0.787	0.243	0.059	3.246	0.001	
23	0.179	0.327	0.107	0.547	0.584	
24	3.030	0.470	0.221	6.444	0.000	
25	0.169	0.189	0.036	0.896	0.370	
26	2.959	0.574	0.330	5.152	0.000	
	0.618	0.050	0.002	12.388	0.000	



Note. Study Name 1- Erciyes University 2018, 2- 19 Mayıs University 2018, 3- Adnan Menderes University 2018, 4-Karamanoglu Mehmetbey University 2018, 5-Sinop University 2018, 6-19 Mayıs University 2019, 7-Bartın University 2019, 8- Gazi University 2019, 9-Fırat University 2019, 10- Gazi University 2019, 11- Gazi University 2019, 12- Manisa University 2019, 13-Marmara University 2019, 14-Muğla Sıtkı Koçman University 2019, 15-Pamukkale University 2019, 16- Erciyes University 2020, 17- Atatürk University 2020, 18-Cukurova University 2020,19-Akdeniz University 2020, 20-Fırat University 2020, 21- Kırşehir Ahi Evran University 2020, 22-Van Yüzüncü Yıl University 2020, 23- Yıldız Teknik University 2019, 24-Marmara University 2019, 25- Erciyes University 2019, 26- Istanbul University 2019.

According to Cooper, Hedges and Valentine (2009), if the I^2 value is above 75%, it indicates high heterogeneity. This result requires the estimation of the real effect size using the random effects model. The effect size calculated in the study using the random effects model, and the weights of the studies in the meta-analysis are shown in Table 2.

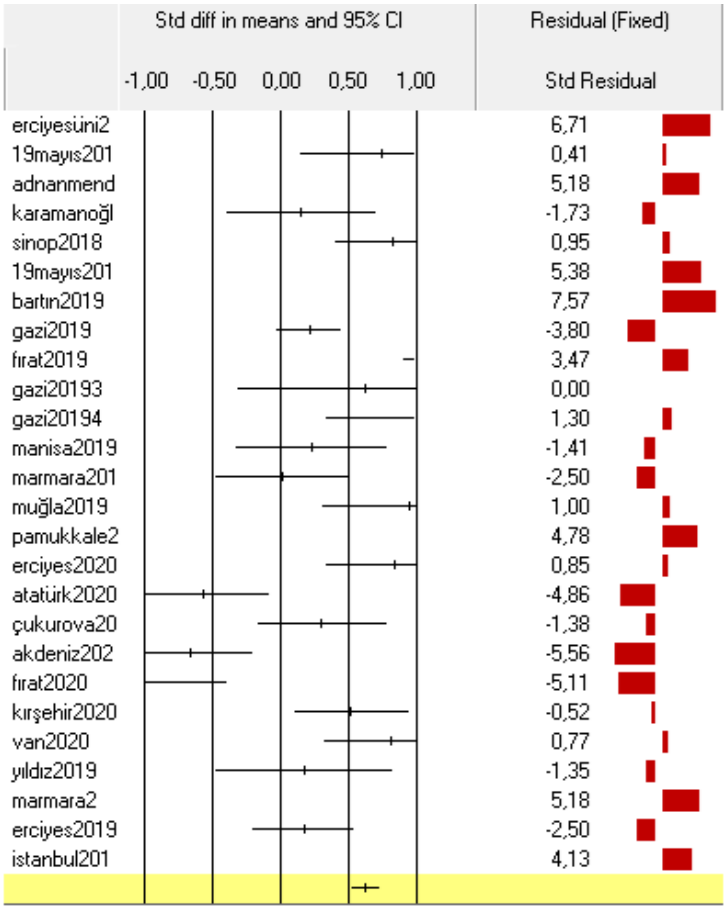


Figure 1: Statistics for each dissertation in forest chart

Forest plots are invaluable in evaluating both meta-analysis results and heterogeneity. In Figure 1, the forest graph of the meta-analysis of 26 dissertations is given. As can be seen, it gives a different point estimate and 95% Confidence interval value for each dissertation. The 26 dissertations examined within the scope of this study were found to be heterogeneous ($Q_{(25)}$=345.536, p<.05).

I^2 statistic: It is the percentage value showing that the variance between studies is due to heterogeneity, not chance.

- 0% to 40%: heterogeneity is very low;
- 30% to 60%: moderate heterogeneity;
- 50% to 90%: sufficient heterogeneity;
- 75% to 100%: high level of heterogeneity.

The significant Q statistic result confirms the assumption that studies are different from one another. The heterogeneity level of the studies is determined as 93% (I^2 = 92.765%). This meta-analysis finding has led to the conclusion that dissertations have high level of heterogeneity.

2. Which group is in favor of the average effect size value in the dissertations on STEM published using the experimental model?

When table 2 is examined, it is understood that the singular examination of the effect sizes of the dissertations included in the study revealed that some dissertations present a great and significant effect in favor of the experimental group. In this study, dissertations were analyzed according to the mean and standard deviation values of the experimental and control groups in the independent groups. The Hedges's g value of the dissertations has been examined. "Small effect" if the Hedges's g value is less than 0.5, if it is between 0.5 and 0.8 the "medium

effect" is, if it is greater than 0.8 and 0.8 it is called “large or wide effect”.”There are 16 dissertations on the effect of activities carried out in independent groups on academic achievement. Dissertations are given in Table 3.

Table 3: Independent group (means, SD’s)

Study name	Data format	Experimental			Control			Hedges’s g
		Group mean	Std-Dev	Sample Size	Group mean	Std-Dev	Sample Size	
1	Independent groups (mean,SD’s)	18.456	3.715	68	10.892	3.792	65	2.004
2	Independent groups (mean,SD’s	15.340	3.770	23	12.130	4.710	23	0.740
3	Independent groups (mean,SD’s	14.744	0.689	22	12.802	0.689	22	**2.768**
4	Independent groups (mean,SD’s	12.070	12.070	27	10.700	3.290	24	0.149
9	Independent groups (mean,SD’s	3.970	0.560	58	3.180	0.640	59	1.304
10	Independent groups (mean,SD’s	61.110	3.850	9	58.330	4.920	9	0.599
11	Independent groups (mean,SD’s	0.710	0.150	13	0.550	0.120	13	1.141
12	Independent groups (mean,SD’s	73.400	19.480	25	68.690	20.580	25	0.231
13	Independent groups (mean,SD’s	4.490	0.400	30	4.090	40.380	34	0.013
14	Independent groups (mean,SD’s	12.900	4.230	20	9.550	2.740	22	0.932
16	Independent groups (mean,SD’s	123.340	12.130	32	112.120	14.310	32	0.836
17	Independent groups (mean,SD’s	3.570	1.060	33	4.120	0.870	33	-0.561
19	Independent groups (mean,SD’s	46.820	11.480	39	55.580	15.420	35	-0.665
20	Independent groups (mean,SD’s	8.710	78.000	21	66.420	13.750	21	-1.011
23	Independent groups (mean,SD’s	4.220	0.730	18	4.060	1.000	18	0.179
25	Independent groups (mean,SD’s	154.510	25.150	47	150.290	24.510	68	0.169

The dissertation, which has a large and wide effect value in independent groups, is "Investigation of the Effect of STEM Activities Prepared for 7th Grade Students in Terms of Different Variables"- PhD dissertation, 2018-Adnan Menderes University. The Hedges's g value of this dissertation is 2.768.

In addition, in this study dissertations were analyzed according to the mean and t values of the paired groups. Hedges’s g value of the dissertations was examined. There are 10 dissertations on the effect of activities carried out in paired groups on academic achievement. Dissertations are given in Table 4.

Table 4: Paired groups (mean, t)

Study Name	Data format	Pre mean	Post mean	Sample Size	Paired Group t-value	Hedges's g
5	Paired groups (mean,t)	13.500	20.730	30	-4.510	0.802
6	Paired groups (mean,t)	6.320	13.850	34	14.310	2.398
7	Paired groups (mean,t)	37.910	40.140	34	51.140	2.768
8	Paired groups (mean,t)	45.160	48.300	70	-1.770	0.209
15	Paired groups (mean,t)	15.300	25.360	30	-12.330	2.192
18	Paired groups (mean,t)	3.660	3.880	18	-1.288	0.290
21	Paired groups (mean,t)	3.790	4.090	25	2.599	0.503
22	Paired groups (mean,t)	3.770	4.180	21	-3.750	0.787
24	Paired groups (mean,t)	27.680	52.440	25	-15.646	**3.030**
26	Paired groups (mean,t)	26.310	42.810	16	12.470	2.959

The dissertation, which has a large and wide effect value in paired groups on STEM and academic achievement, was " The effects of digital game-based STEM activities on students' interest in STEM fields and scientific creativity: Minecraft case"- Postgraduate dissertation, 2019- Marmara University. The Hedges's g value of this dissertation is 3.030.

Odds ratios are widely used in experimental studies. There are three reasons for this. Firstly, they provide an estimate (with confidence interval) for the relationship between two binary ("yes or no") variables. Secondly, they enable us to examine the effects of other variables on that relationship, using logistic regression. Thirdly, they have a special and very convenient interpretation in control studies (Bland & Altman, 2000). Odds ratio (OR) can be interpreted according to the value it receives as follows;

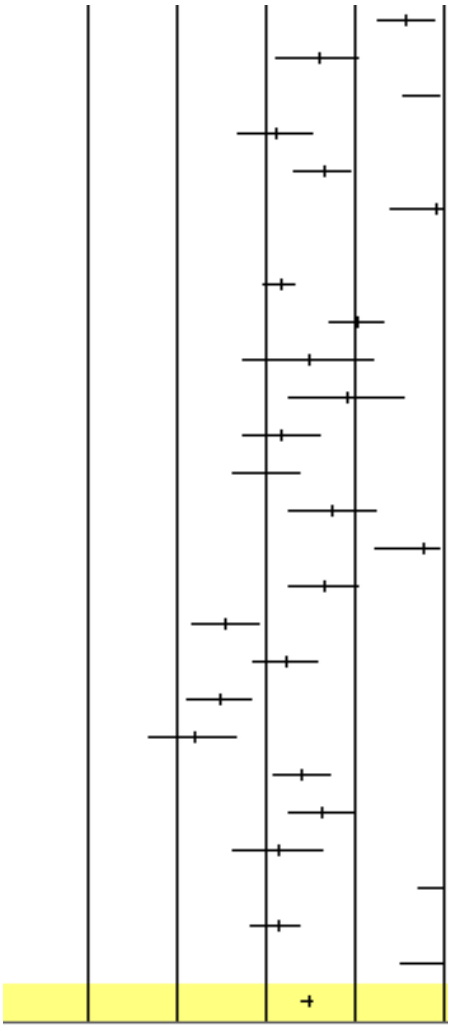
- When OR=1, it can be said that the curious factor has no effect on increasing or decreasing the probability of the investigated situation.
- When OR<1, the curious factor has a decreasing effect on the probability of the investigated condition.
- When OR>1, the curious factor has an effect that increases the probability of the investigated condition.

The 95% confidence interval (CI) is used to estimate the precision of the Odds Ratio. A large CI indicates a low level of precision of the odds ratio, whereas a small CI indicates a higher precision of the OR. It is important to note however, that unlike the p value, the 95% CI does not report a measure's statistical significance. In practice, the 95% CI is often used as a proxy for the presence of statistical significance if it does not overlap the null value (Szumilas, 2010).

The odds ratios, z and p values of the dissertations analyzed in the study are given in Table 5. When the Odds ratios in the table are examined, it is seen that 22 out of 26 dissertations have OR > 1. The odds ratio found in the meta-analysis of dissertations on STEM and academic achievement revealed that the dissertations analyzed had a great effect together. When Table 5 is examined, it is seen that the odds ratios of the wide majority of dissertations are very high. This may be related to the fact that the meta-analysis codes created before the research were well determined.

Table 5: Odds rate of dissertations

Study Name	Odds ratio	Z-Value	p-Value	Odds ratio and 95% CI
1	38.699	9.463	0.000	
2	3.915	2.466	0.014	
3	166.058	6.622	0.000	
4	1.315	0.537	0.591	
5	4.453	3.897	0.000	
6	85.741	7.145	0.000	
7	810.356	8.141	0.000	
8	1.468	1.751	0.000	
9	10.821	6.441	0.000	
10	3.131	1.303	0.193	
11	8.470	2.772	0.006	
12	1.532	0.828	0.408	
13	1.025	0.054	0.957	
14	5.600	2.915	0.004	
15	59.330	6.559	0.000	
16	4.638	3.242	0.001	
17	0.357	-2.259	0.024	
18	1.734	1.259	0.208	
19	0.296	-2.808	0.005	
20	0.154	-3.137	0.002	
21	2.567	2.439	0.015	
22	4.412	3.246	0.001	
23	1.393	0.547	0.584	
24	291.704	6.444	0.000	
25	1.362	0.896	0.370	
26	285.579	5.152	0.000	
	3.123	12.354	0.000	



It has been seen that the dissertations written according to the experimental model related to STEM and academic achievement examined in the research contribute to the probability of the researched situation.

Table 6: Findings in relation to the Meta-Analysis effect size calculated according to the random effects model

ES	**Z**	**Q**	**I^2**	**S_{error}**	**ES_{lower}**	**ES_{upper}**
0.618	12.388	345.536	92.765	0.050	0.520	0.716

$p<.05$

According to Table 6, the average effect size value is significant ($Z=12.388$, $p<.05$). The average effect size value, on the other hand, is 0.618, and has been found to be positive. In this case, it can be said that the process effect is in favor of experimental group.

Based on this finding, it can be said that the academic achievements of the students in classes taught using the STEM education method are higher than the achievements of students in classes taught using other methods and techniques.

3. Is there publication bias among STEM dissertations published using the experimental model?

Since it is more preferable in the literature to include published studies in meta-analysis, the possible biases in these studies are also reflected in meta-analysis. This problem is commonly referred to as "publication bias." Publication bias is not only a problem specific to meta-analysis and systematic review (Card, 2012; Rosenthal & DiMatteo, 2001).

Whether the dissertations included publication bias was examined using the funnel plot. The chart showing the publication bias in this study is presented in Figure 2. The name "funnel plot" comes from the idea that as the sample size of the studies increases, the accuracy of the effect size estimation of the application will also increase. Funnel plots are a simple scatter plot of the estimated effect size in each study versus a measure of the sample size of the studies.

Funnel plots are created with the X-axis showing effect sizes values, while the Y-axis showing sample size, variance, or standard error (Sterne & Harbord, 2004). Sterne and Egger (2001) consider choice of axis in funnel plots of meta-analyses with binary outcomes. Although sample size or functions of sample size have often been used as the vertical axis, this is problematic because the precision of an effect estimate is determined by both the sample size and by the number of events. Thus, studies with very different sample sizes may have the same standard error and precision and vice versa. Therefore, the shape of plots using sample size on the vertical axis is not predictable except that, in the absence of bias, it should be symmetric (Bradburn, Deeks & Altman 1998). Small sample studies cause data irregularities as they have low methodological quality. This situation cause funnel asymmetry. Poor choice of effect measure may also result in funnel-plot asymmetry (Deeks & Altman 2001).

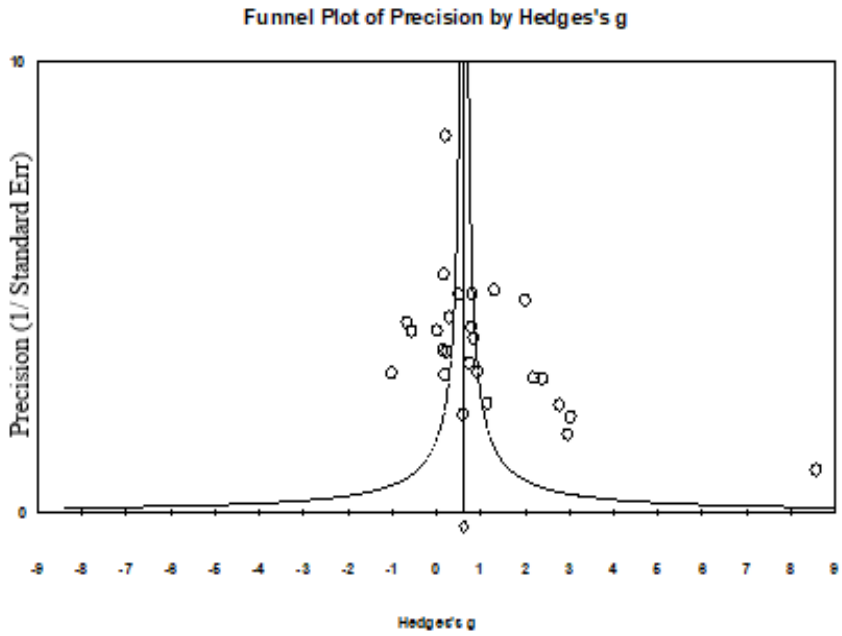


Figure 2: Funnel plot of precision by Hedges g for publication bias

A meta-analysis study provides a mathematically accurate synthesis of the studies included in the research. If a biased presentation of the studies studied on the meta-analysis is made, the average effect size obtained also reflects this bias. Funnel Plot is examined, it is understood that the vast majority of the dissertations examined within the scope of meta-analysis are clustered on the end and inside part of the funnel plot. This indicates that the dissertations analyzed have a high contribution to the meta-analysis. It has been determined that both sides of the funnel plot are not symmetrical. The number of studies on the right side of the figure spoil the symmetry. The unsymmetrical funnel is also an indicator of publication bias. In this graph, each dissertation is represented by a circle. Effect sizes Hedges g values are on the horizontal axis, while standard errors are on the vertical axis.

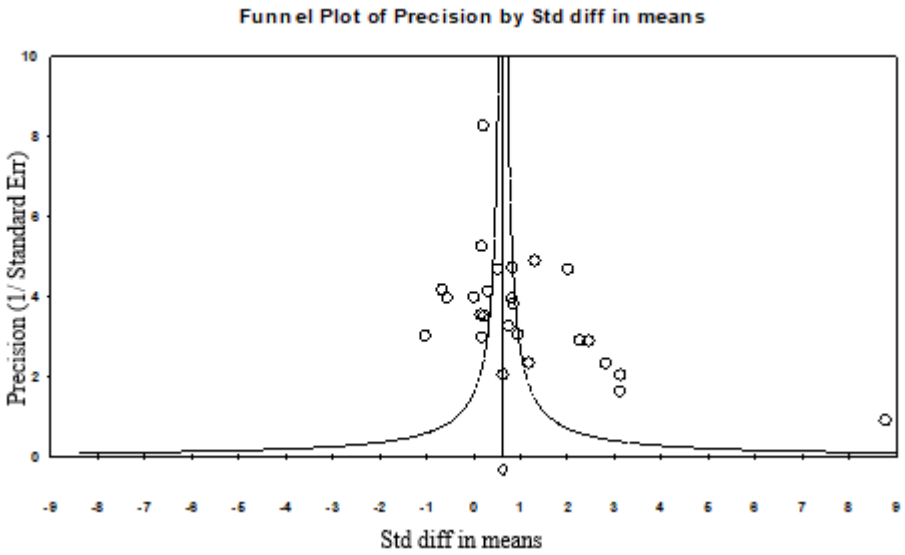


Figure 3: Funnel plot of precision by Std diff in means for publication bias

When the funnel plot is examined for the standardized mean difference, it is seen that the distribution of the publication has a shape similar to that of Hedges's g chart. This situation reveals that the dissertations examined have a high contribution to the meta-analysis. This finding points to the small number of study groups in the dissertations in which the effect of STEM education on academic achievement is examined. Low methodological quality due to the small number of samples in the experimental and control groups causes asymmetric graphics and publication bias.

4. Discussion

The first thing to do in meta-analysis studies is to examine the heterogeneity of the studies that are the subject of the research. The significant Q statistic result confirms the assumption that studies are different from one another. In determining the heterogeneity considered in model selection, other heterogeneity measures should be taken into account besides the Q statistic. When the number of studies is large, even if the heterogeneity is not high, heterogeneity can be found to be statistically significant with the Q statistic.

1) It has been determined that the dissertations examined within the scope of the research have a high level of heterogeneity. Different study patterns, study quality, bias caused by study selection, other bias effects, and the use of different statistical methods may be considered as possible causes of heterogeneity. One of the reasons for the heterogeneity in the dissertations examined may be due to the insufficient number of participants in the study groups. Another reason may be that the experimental and control groups were not determined by random assignment in the majority of dissertations. In addition, it can be said that studies without post-test scores are also the cause of this. It is difficult to find a concrete reason in such studies. Further work may need to be done to find and resolve possible causes.

As a result of this meta-analysis study, in which dissertations made with an experimental model were examined that examined the effect of STEM education on students' academic success, it was found that the academic success of students receiving STEM education was higher than that of students who did not receive this education. Similar results were shared in the studies carried out as well: Yıldırım & Altun (2015) conducted an experimental study with the objective to support the study on STEM education and engineering practices. As a result of the study, it was determined that STEM education and engineering practices are effective in improving students' achievements. The aim of the research conducted by Gokbayrak & Karısan (2017) is to investigate the effects of STEM-based activities carried out in the laboratory course on the science process skills of prospective teachers. It was determined that there was a significant difference in favor of the experimental group between the post-application scores of the experimental group students who participated in STEM-based science laboratory activities and the test achievement scores of the control group students who did not participate in the activities. The scientific process

skills test revealed a significant difference in the analysis results in favor of the experimental group, and that STEM has a positive effect on the development of scientific process skills. Yıldırım & Selvi (2017) focused on determining the effect of STEM practices on high school students' attitude towards STEM, their motivation towards science, as well as their inquisitive learning skills, academic achievement and permanent learning. Upon comparison of the pre-test and final test scores of students' academic achievements, the results show a significant different in favor of the final test. In relation to students' motivation towards science, the practices established a difference between the pre-test and final test results of the experimental group and the pre-test and final test results of the control group.

2) As seen in the literature, studies emphasizing the effects of STEM activities on school success have been encountered. It has been seen that these trainings, which are very popular in science, mathematics and technology, contribute to the motivation of the students as well as the success of the students. When the dissertations made in Turkey on this subject are examined, it is seen that there is a similar situation to the research results. When the dissertations published in this study were examined one by one, it was seen that they presented significant findings about STEM and academic success. When the common effects of the studies presented together on this subject were analyzed with meta-analysis, it was concluded that the effect sizes were large. In study the average effect size value is significant. The average effect size value has been found to be positive. In this case, it can be said that the process effect is in favor of experimental group.

The total effect size value was found to be positive and significant in dissertations conducted on STEM education between 2018 and 2020. The effect size in this meta-analysis study is within the powerful effect size range according to the Cohen, Manion and Morrison (2007) classification. It is seen that the effect sizes of dissertations examining the effect of STEM education on academic achievement are positive and large. Based this finding, studies examining the effect of STEM education on students' academic achievements, their motivation, attitudes, perceptions and creativity together can be analyzed with the results interpreted using the meta-analysis method.

A major goal of developing effect size measures is to provide a standard metric that meta-analysts and others can interpret across studies that vary in their dependent variables as well as types of designs. Researchers should keep in mind that observed effect sizes in a study can differ from the effect size in the population, and there are reasons to believe overestimations are common given current publication practices where journals mainly accept studies that observe statistically significant effects. Early publications of a given finding tend to overestimate the effect size due to regression to the mean (Fiedler, Kutzner & Krueger, 2012).

For these reasons, it is inadvisable to focus solely on an a-priori power analysis when the sample size for a future study is determined (unless a very accurate effect size estimate is available), and researchers should pay attention to alternative approaches to plan sample sizes (Maxwell & Delaney,2004). Current dissertations are limited to effect sizes for standardized mean differences. Such comparisons are quite common in experimental studies, but they almost never cover all possible research designs. Future dissertations about effect size calculations should provide software or spreadsheets to make it as easy as possible for researchers to implement these calculations into their workflow. It should be known that the easiest way to facilitate cumulative science is to share the data of the reported studies. Especially for mixed designs or analyses with covariates, where calculating I^2 becomes quite complex, sharing the data will always enable researchers who want to perform a meta-analysis to calculate the effect sizes they need.

3) Numerous findings show that studies with a large effect size are published more often than those with a small effect size. The asymmetry in the funnel plot indicates publication bias. Although there is no way to prevent this situation, it can be recommended that researchers only include large-sample studies in meta-analysis. The vast majority of the dissertations examined within the scope of the study are observed to cluster on the end and inside of the funnel plot, with high contribution to the common effect. Additionally, the studies are not distributed symmetrically on both sides of the funnel plot. In experimental dissertations having a sample of 16-18 people have low effect size, while the effect size in studies with 70 people was very high. This indicates that the effect size value is highly influenced by the sample. As the sample size increases, sampling bias goes down, and therefore high-powered studies provide better effect size estimates for meta-analyses than studies with low power. The

choice of an effect size calculation depends on the research question and the experimental design. It is important to explicitly state which effect size is calculated, and to make a motivated choice about which effect sizes to report. STEM education practices can be commenced as of the preschool period, with students gaining knowledge of science, mathematics, engineering and technology education subjects through inquisition by providing them the suitable learning atmosphere. Besides dissertations, the effect of STEM in meta-analysis studies with large samples can be examined in publications such as papers and reports as well. In order to prevent bias in studies, it is advised that the sample in experimental studies be no less than 20 people. The use of STEM in class programs can be emphasized to observe its impact on academic success. Revisions can be performed based on the program. Classes including the STEM approach and practices can be added to the bachelor's program.

References

Akgöz, S., Ercan, I., & Kan, I. (2004). Meta-analysis. *Journal of Uludag University Faculty of Medicine, 30* (2),107-112.
Retrieved from https://dergipark.org.tr/tr/pub/uutfd/issue/35311/391976

Bland, J. M., & Altman, D.G. (2000). *Statistics notes. The odds ratio.* BMJ. 27;320 (7247):1468.

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher, 70*(1), 30. ISSN-2158-0502

Betts, M., & Lansley, P. (1993). Construction management and economics. A review of the first ten years. *Construction Management and Economics, 11*(4), 221-245. https://doi.org/10.1080/01446199300000024

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). *Introduction to meta–analysis*. UK: John Wiley & Sons Ltd.

Bradburn, M. J., J. J. Deeks, & D. G. Altman. (1998). *Metan – an alternative meta-analysis command*.Stata Technical Bulletin 44: 4–15. In Stata Technical Bulletin Reprints, vol. 8, 86–100. College Station, TX: Stata Press.

Capraro, R. M. (Ed.). (2013). *STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach* (2. ed). Sense.

Card, N. A. (2012). *Applied meta-analysis for social science research.* New York: The Guilford Press.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed.). New York, NY: Routledge.

Cooper, H., Hedges, L. V., & Valentine, J. C. (2009). *The handbook of research synthesis and meta-analysis* (2. Edition). New York: Sage Publication.

Cortés-Sánchez, J. D., Bohle Carbonell, K., & Guix, M. (2020). *Innovation research in management and stem for sustainability in developing countries insights from bibliometrics in the global south*. Universidad del Rosario.

Çakar, V. (2019). *The effect of using flipped classroom model in physics on learning products* [Unpublished M.Appl.Psy. thesis]. Zonguldak Bülent Ecevit University.

Çorlu, M. S. (2012, June 27-30). *A theoretickal framework for STEM education*. [Paper presentation]. X. National Science and Mathematics Education Congress, Niğde.

Dedetürk, A. (2018). *Developing and applying teaching activities with Fetemm's approach to 6th grade sound and researching its effect on success* [Unpublished M. Appl. Psy. thesis]. Erciyes University.

Deeks, J. J. & D. G. Altman. (2001). Effect measures for meta-analysis of trials with binary outcomes. *In Systematic Reviews in Health Care: Meta-Analysis in Context.* 2d ed., ed. M. Egger, G. Davey Smith, and D. G. Altman, 313–335. London: BMJ Publishing Group.

Duygu, E. (2018). *The effect of STEM education on scientific process skills and STEM awareness in a simulation-based inquiry learning environment* [Unpublished M. Appl. Psy. thesis]. Kırıkkale University.

English, L. D., & King, D. T. (2015). STEM learning through engineering design: Fourth-grade students' investigations in aerospace. *International Journal of STEM Education, 2*(1), 14. https://doi.org/10.1186/s40594-015-0027-7

English, L. D. (2016). STEM education K-12: Perspectives on integration. *International Journal of STEM Education, 3*(1), 3, s40594-016-0036-1. https://doi.org/10.1186/s40594-016-0036-1

English, L. D. (2017). Advancing elementary and middle school STEM education. *International Journal of Science and Mathematics Education, 15*(S1), 5-24. https://doi.org/10.1007/s10763-017-9802-x

Ercan, S. (2014). *The usage of engineering practices in science education: effects of design based science learning on students' academic achievement* [Unpublished M. Appl. Psy. thesis]. Marmara University.

Fiedler, K., Kutzner, F., & Krueger, J. I. (2012). The long way from α-error control to validity proper problems with a short-sighted false-positive debate. *Perspect. Psychol. Sci*. 7, 661–669. https://doi.org/10.1177/1745691612462587

Gazibeyoğlu, T. (2018). *Investigating the effects of stem practices on the 7th grade students' attitudes towards science lesson* [Unpublished M. Appl. Psy. thesis]. Kastamonu University.

Gonzalez, H. B., & Kuenzi, J. (2012). *Congressional research service science, technology, engineering, and mathematics (STEM) education: A primer*. USA: Congressional Research Service.

Gökbayrak, S., & Karışan, D. (2017). An investigation of the effects of stem based activities on preservice science teacher's science process skills. *The Western Anatolia Journal of Educational Sciences, 8*(2),63-84. https://doi.org/10.14687/jhs.v14i4.5017.

Grund, S., & Grote, G. (2004). Pedagogical aims, course characteristics and their relation to students` behaviour: A case study on blended learning. *Swiss Journal of Educational Science, 26*(2), 305-326. https://doi.org/10.24452/sjer.26.2.4682

Hedges, L. V., & Olkin, I. (1985). *Statistical methods for meta–analysis.* USA: Academic Press Inc.

Higgins, J. P. T., & Green, S. (Eds.). (2011). *Cochrane handbook for systematic reviews of interventions* (Version 5.1.0). Hoboken, NJ: Wiley.

Israel, M., Maynard, K., & Williamson, P. (2013). Promoting literacy-embedded, authentic STEM instruction for students with disabilities and other struggling learners. *Teaching Exceptional Children, 45*(4), 18-25. https://doi.org/10.1177/004005991304500402

Karasar, N. (2014). *Methods of scientific research* (24. printing). Ankara: Nobel Publishing House.

Kearney, C. (2016). Efforts to increase students' interest in mathematics, science and technology studies and careers. *National awards received by 30 countries measures - 2015 report*. Brussels: European School Network.

Kuru, N., & Akman, B. (2017). Examining the science process skills of preschoolers with regards to teachers' and children' variables. *Eğitim ve Bilim, 42*(190), 269- 279. http://dx.doi.org/10.15390/EB.2017.6433

Lacey, T.A., & Wright, B. (2009). *Occupational employment projections to 2018.* Monthly Labor Review, (18),82-109. Retrieved from https://www.bls.gov/opub/mlr/2009/11/art5full.pdf

Lantz, H. B. (2009). *Science, technology, engineering, and mathematics (STEM) education what form?* What function. Report, CurrTech Integrations, Baltimore.

Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2013). STEM: country comparisons: international comparisons of science, technology, engineering and mathematics (STEM) education. Final report.

Maxwell, S. E., & Delaney, H. D. (2004). *Designing experiments and analyzing data: A model comparison perspective*, 2nd Edn. Mahwah, NJ: Erlbaum.

MNE. (2016). *STEM Education Report.* Ankara: Ministry of National Education - General Directorate of Innovation and Educational Technologies. https://yegitek.meb.gov.tr/STEM_ *Education _ Report*.pdf

Morrison, J. (2006). *Attributes of STEM education: The student, the school, the classroom.* Baltimore: TIES.

Roberts, A. (2012). *A justification for STEM education*. Technology and Engineering Teacher, 74 (8), p.1-5. File.aspx (iteea.org)

Roehring, G.H., Moore, T.J., Wang, H.-H., & Park, M.S. (2012). Is adding the E enough? Investigating the impact of K-12 engineering standards on the implementation of STEM integration. *School Science and Mathematics, 112*(1), 31-44. https://doi:10.17509/ajsee.v2i1.35097

Rosenthal, R., & DiMatteo, M. R. (2001). Meta-analysis: Recent developments in quantitive methods for literature reviews. *Annu. Rev. Psychol.,* 52:59-82.

Sanders, M. (December 2009). *STEM, STEM education, STEMmania.* The Technology Teacher, *68*, 20-26. ISSN-0746-3537.

Saunders, B.D., & Trapp, R.G. (1994). *Basic and clinical biostatistics.* 2nd Edition, Appleton & Lange, Norwalk CT, p. 1-227.

Shaughnessy, J. M. (2013). By way of introduction: Mathematics in a STEM context. *Mathematics Teaching in the Middle School, 18*(6), 324. https://doi.org/10.5951/mathteacmiddscho.18.6.0324

Smolentseva, A. (2015). Globalization and the research mission of universities in Russia. *In Higher education in the BRICS countries* (pp. 399-421). Springer, Dordrecht.

Sterne, J. A. C., & Harbord, R. M. (2004). Funnel plots in meta-analysis. *The Stata Journal, 4*(2), 127-141. https://doi.org/10.1177/1536867X0400400204

Szumilas M. (2010). Explaining odds ratios. *Journal of the Canadian Academy of Child and Adolescent Psychiatry*, *19*(3), 227–229. https://doi.org/10.1136/bmj.c4414

Suratno, Wahono, B., Chang, C-Y., Retnowati, A., & Yushardi. (2020). Exploring a direct relationship between students' problem-solving abilities and academic achievement: A STEM education at a coffee plantation area. *Journal of Turkish Science Education,17*(2), 211-224. https://doi.org/10.36681/tused.2020.22

Tseng, K.H., Chang, C.C., Lou, S.J., & Chen, W.P. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (pjbl) environment. *International Journalof Technology and Design. 23*(1), 87-102. ISSN-0957-7572.

White, D. W. (2014). What is STEM education and why is it important? *Florida Association of Teacher Educators Journal, 1*(14), 1-8. Retrieved from http://www.fate1.org/journals/2014/white.pd

Yıldırım, B., & Altun, Y. (2015). Investigating the effect of STEM education and engineering applications on science laboratory lectures. *El-Cezeri Journal of Science and Engineering, 2*(2), 28-40. Retrieved from https://dergipark.org.tr/tr/pub/ecjse/issue/4899/67132. ISSN-2148-3736.

Yıldırım, B. (2016). 7. Examining the effects of science and engineering mathematics (stem) applications and full learning integrated into the 7th grade science lesson [Unpublished M. Appl. Psy. thesis]. Gazi University.

Yıldırım, B., & Selvi, M. (2016). Examination of the effects of STEM education integrated as a part of science, technology, society and environment courses. *Journal of Human Sciences, 13*(3), 3684-3695. https://doi.org/10.14687/jhs.v13i3.3876