The Effect of Stem Education on Academic Performance: A Meta-Analysis Study

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ABSTRACT
STEM education is applied to raise individuals having 21st-century skills based on the integration of science, technology, engineering, and mathematics. This paper aims to present the overall effect of STEM education on students' academic achievement by analyzing 64 research findings obtained from 56 quantitative studies published between 2014 and 2021. Relevant studies were identified from the databases of scholarly publications such as ERIC, Web of Science, EBSCOHost, Google Scholar, SCOPUS, ProQuest, CHE Thesis Center. The sample was then meta-analytically examined using the CMA program. Education level, duration of the application, disciplines, and publication type were determined as moderator variables. The results showed that the effect of STEM education on students' academic success was statistically higher (g= 1.150) in the random-effects model. A heterogeneous distribution was obtained from the sample. Further subgroup analyzes using Analog ANOVA revealed that disciplines (Qb= 921.394; p= .000), and publication type variables were statistically significant (Qb= 7.229; p= .007). With respect to the disciplines, the effects of STEM education showed the largest effect size of 1.156 in the discipline of science. Regarding the publication type, national studies were presented the largest effect size of 1.155.
Keywords: STEM education, academic performance**,** science, technology**,** engineering**,** mathematics**,** meta-analysis

INTRODUCTION

Recent advances in information and communication technology continue to affect each aspect of society, along with important implications in the field of education. Countries aiming to be a leader in the scientific and technological race also attach great importance to science and mathematics education. For this reason, in order not to fall behind in the technological race, they have adopted the basic aim of raising individuals who understand science and mathematics conceptually well, associate these concepts with daily events, and can solve the problems they face in daily life with the information transferred in schools (Çepni, 2017). Dinçer (2014) argues that the basic resource of the economy is individuals who can produce knowledge and use them when necessary. For this reason, it is of great importance to educate the new generation with skills such as analytical, creative, and critical thinking, which are called 21st century skills. The way to gain these skills is through "STEM", in other words, science, technology, engineering, and mathematics which is the basis of today's and future science and technological developments. STEM education, a workforce consisting of individuals who are aware of STEM literacy, aims to continue their current work in the STEM field, to produce innovations that will provide an economic advantage to countries, and to be competent in future business areas (Thomas, 2014).

William (2011) defines STEM education as an approach that supports student participation using engineering and technology and improves students' learning in science and mathematics. In addition, Israel, Maynard, and Williamson (2013) describe it as student-centered and collaborative learning beyond the contexts of four STEM domains. STEM education is an approach that eliminates the boundaries between disciplines by enabling students to understand the world as a whole rather than parts (Lantz, 2009). Although there is no consensus on the exact definition of STEM education (Thomas, 2014), the general belief is that STEM involves military, economic, high-level thinking that brings together disciplines, leads to effective and qualified learning, takes existing knowledge, and puts it into daily life (Yıldırım & Altun, 2014). According to Şahin et al. (2014), STEM education aims to enable individuals to look at problems from a different perspective between fields by gaining skills and knowledge with a totalitarian approach to education.

The STEM curriculum includes moving beyond the four walls of the classroom by incorporating informal learning

and continuously expanding learning methods. It is based on combining formal and informal activities, such as mobile device use or museum visits, and it improves learners' interest in learning and increases their participation (Wang & Chiang, 2020). A brief literature analysis shows that many independent studies are examining the effect of STEM education on students' academic success. An examination of the studies in the literature demonstrates that some studies reported that STEM education increased academic success (Cotabish et al., 2014; Çetin, 2019; Dedetürk, 2018; Ercan, 2014; Gülen, 2016; Irkıçatal, 2016; İnce et al., 2018; İzgi, 2020; Olivarez, 2012; Ozan & Uluçınar Sağır, 2020; Salman-Parlakay, 2017; Uçar, 2019; Yaki et al., 2019; Yıldırım, 2016; Yıldırım & Altun, 2015; Yıldırım & Selvi, 2017; Young, Young & Ford, 2017). Given this situation, this study aims to conduct a reliable meta-analysis study called analysis of analysis (Glass, 1976), in a systematic effort to interpret the findings of previous studies and to guide future research. Although there are a number of meta-analysis studies in the literature (Angelo et al., 2014; Ayverdi & Öz-Aydın, 2020; Becker & Park, 2011; Belland et al., 2017; Saraç, 2018; Yücelyiğit & Toker, 2021), there is not a comprehensive international meta-analysis for the period 2014-2021. For this reason, a meta-analysis study on this subject is considered necessary to investigate the quantitative results of existing studies which have examined the effect of STEM education on academic achievement. The current study set out to synthesize these results and establish the overall magnitude of the effect. For this main purpose, answers to the following questions were sought:

1. What is the effect size of STEM education on academic success?
2. How does the effect of STEM education on academic success vary as a function of moderator variables (education levels, publication type, disciplines, and intervention duration)?

THEORETICAL FRAMEWORK

STEM is the abbreviation of Science, Technology, Engineering, and Mathematics (Gonzalez and Kuenzi, 2012). Different definitions have been put forward for STEM education. According to Morrison (2006), STEM education, which is a meta-discipline, is a new discipline in which other disciplines are integrated. Dugger (2010) also states that STEM education presents the including disciplines as intertwined as in daily life; thus enables students to perceive the world as a whole. On the other hand, Çorlu, Capraro, and Capraro (2014) define STEM education as the structuring of knowledge, skills, and thoughts by teachers and learners with the cooperation of more than one STEM field. In addition, Vasquez, Sneider, and Comer (2013) define STEM education as an interdisciplinary learning and teaching approach that removes the traditional barriers between science, technology, engineering, and mathematics disciplines. In the light of these definitions, it can be inferred that STEM education aims to teach science, engineering, technology, and mathematics courses in an interdisciplinary manner. Moreover, the major goal of STEM education is to help students to develop academic performance and to gain cognitive and critical competencies.

Radical changes have been put into force in the curriculum in order to raise young generations with 21st century skills. In the 1990s, the USA adopted a holistic approach to education in the curriculum in which the disciplines of science, technology, engineering, and mathematics are addressed together (Bybee, 2010). This approach is called STEM. The scientific and technological competition between developed countries and the trend of raising people with 21st century skills has led to the opening of STEM schools in many states in the USA, where teachers openly integrate engineering into lessons. Furthermore, in Europe, several STEM projects were carried out to apply science education based on questioning and increase students' interest in science (Akgündüz et al., 2015). On the other hand, Turkey keeping up with developments in the world, began to make STEM studies at the university level at first. Thus, a STEM Center was established at Istanbul Aydın, Hacettepe, and Bahçeşehir University established a STEM laboratory (Akgündüz et al., 2015). Then, in 2016, a report called STEM Education Report was prepared by the Ministry of National Education General Directorate of Innovation and Educational Technologies. In the report, it was stated that the 2015-2019 Strategic Plan aimed for strengthening STEM, and also the studies carried out in the 7th and 8th-grade Technology Design courses in schools are in accordance with the STEM logic. As a result, it can be observed that STEM education has become an indispensable part of 21st-century education programs (NRC, 2013). The age we are in expects individuals to be able to both produce and solve problems. STEM education has emerged on the education scene as it brings these competencies and approaches problems with a totalitarian perspective (Bybee, 2010). STEM education aims to bring these skills to the individual by focusing on literacy skills such as creative thinking, critical thinking, problem-solving, and collaborative work (Özdemir, 2016). Equipping individuals with such skills contributes to human development and promotes innovation, helping nations grow and compete in the global knowledge economy.

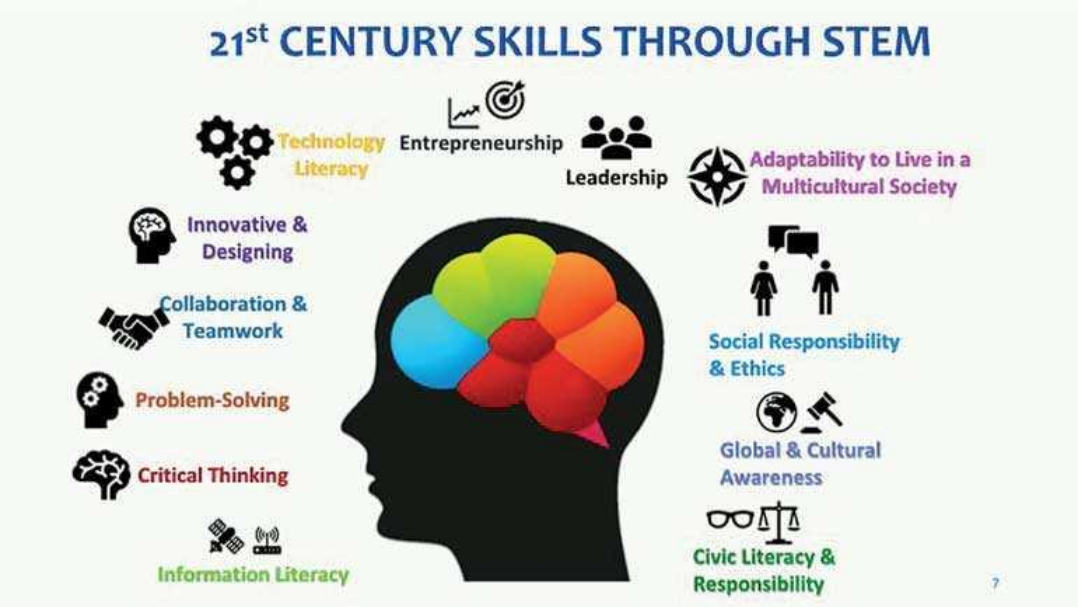

Figure 1. 21st century skills through STEM (Alwis, 2018)

In the 21st century, it has become significant for every country to raise individuals who are scientifically literate, who can keep up with the changing information and technology, who will respond to the needs of the education and business world, and who have high-level of cognitive skills. Along with the rapid development of information and communication technologies, 21st century skills have become different from 20th century skills. Therefore, the change in expectations of individuals in 21st century has required to take necessary measures in parallel with this change in educational goals. In the necessity of increasing the quality standards of education, students are required to have the skills to solve their daily problems and contribute to the needs of society (Şahin, Ayar & Adıgüzel, 2014). 21st skills are expressed in Figure 1 as being creative, innovative and thinking critically, solving problems, having communication skills, working in a team, information and communication technologies literacy, local and universal citizenship awareness, life and career awareness. On the other hand, Bybee (2010) addressed 21st skills as critical thinking, creativity, cooperation, motivation, and metacognitive skills. Hence, it is possible to comment that the emerging science and technology of our present century have shaped both education system and expectations for a future individual. STEM education is considered as a precious way to make the education system keep up with the developments and to meet the expectations.

The fact that the 21st century is an era in which dizzying developments are experienced in science, technology, art, economy and many fields also affects the education systems of countries. Countries are making reforms to their education policies in order to raise individuals who can prepare themselves for this rapid development and changing process, who make up the society, and who have the 21st century and life skills. Some of these skills are taking responsibility, being innovative, having communication skills, taking risks, having a critical point of view, science and technology literacy, creativity, etc. (Lin et al., 2019). As STEM education is a holistic perspective enabling individuals to both acquire 21st century skills and reach quality in education, it enhances individuals' competencies mentioned. Consequentially, a brief literature analysis shows that STEM education develops students' problem-solving skills, provides the opportunity to develop their creativity and design in the field of engineering by using their basic knowledge and skills, allows students to think logically and critically and to develop an interdisciplinary perspective and associate the learned information, enables to understand and explain the nature of technology by equipping them with 21st century skills.

METHOD

Research Model

The meta-analysis statistical method was selected to conduct a synthesis of the combined experimental findings obtained from relevant individual studies, and interpreting them in effect size form (Card, 2012; Wolf, 1986). The current study followed the meta-analytic procedures suggested by Glass et al. (1981), which include (1) collecting relevant studies, (2) coding the features of the studies, (3) calculating the effect sizes of each study's outcome measures, and (4) investigating the moderating effects of a study's characteristics on the outcome measures.

Collecting the Relevant Studies

This research was evaluated by E-97132852-302.14.01-31805 numbered meeting of XXX University Social and Human Sciences Ethics Committee on 31.03.2021 and was found ethically appropriate. Accordingly, the data were

collected from research articles, master and doctoral theses that met the inclusion criteria given in Table 1. Studies were identified with the help of national and international databases in the field of education and published electronically such as ERIC, Web of Science, EBSCOHost, Google Scholar, SCOPUS, ProQuest, CHE Thesis Center. In addition, the bibliography sections were also examined in the studies reached, in an effort to identify earlier works that may not have been published electronically.

Table 1: Inclusion criteria for the selection of studies

Criteria	**Inclusion**
Publication period	Completed between 2014 and 2020.
Publication type	An article published in a national or international refereed journal or a master's / doctoral thesis.
Language	Turkish or English.
Research design	An experimental design with a control group. The control group should be taught with the traditional method, while the experimental group with the STEM.
Outcome	Academic performance
Implementation	Measure the effect of the STEM education in the field of educational settings.
Accessibility	Full text available.
Data	Sample size, standard deviation, and mean values.

The researchers identified some keywords to assist the resource search. Binary combinations of such keywords as "STEM education and academic achievement", "STEM learning and learning outcome" were scanned in all databases during the research. Overall, the keyword search provides 11467 studies. Next, 4536 studies were eliminated because of the duplication, and 6932 studies were removed for not being suitable for the research problem. Considering the inclusion criteria, 77 studies were eliminated, leaving 56 studies to form the study sample. However, as Acar (2018), Olivarez (2012), James (2014), Judson (2014) showed the effect of STEM learning on academic success in their study by working with different disciplines, and Cotabish et al. (2014) showed on different grades, the researchers were able to increase the size of the sample to 64. A Prisma flow diagram showing how the study sample of 56 out of 11467 papers was reached is given in Figure 2.

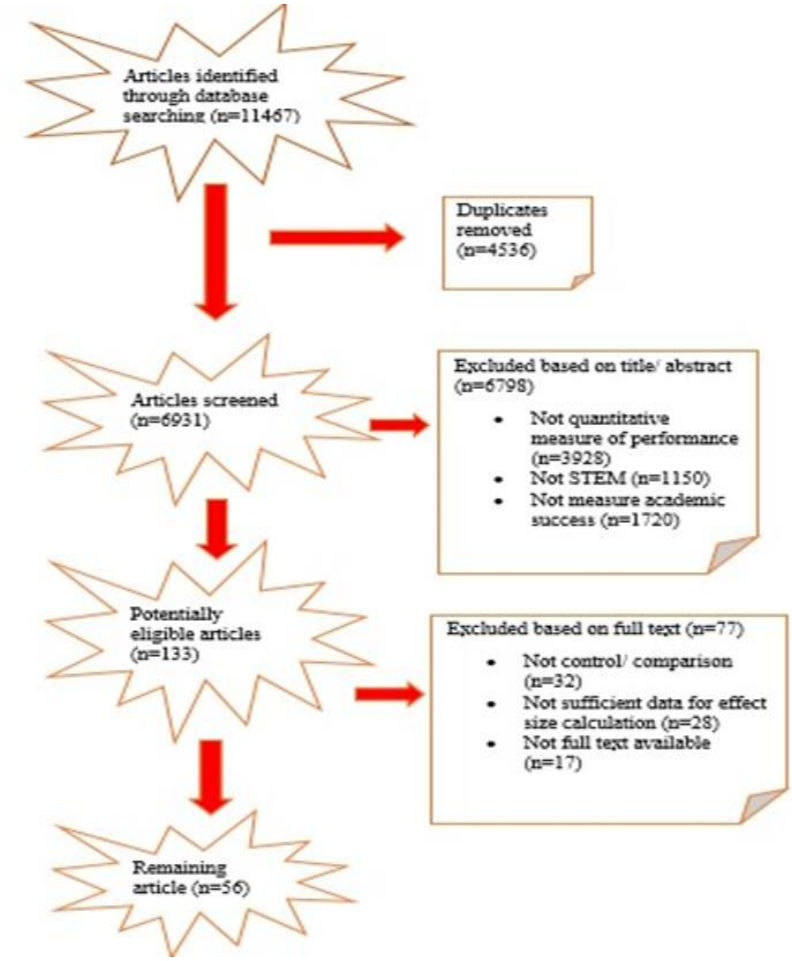

Figure 2. Prisma Flow Diagram

Coding the Features of the Studies

In this study, a coding form consisting of three parts as "study identity", "data of the study, and "study content" was developed to record the studies reached as a result of the literature review. In the first part, the author's surname, and publication year were coded. In the second part, the data of the studies were coded. In this section, pre-test sample size, mean, and standard deviation values, post-test sample size, standard deviation, and mean of the control, and experimental groups, respectively, were recorded. In the third part, the data of the moderator variables were coded. These variables were determined as the type of publication, the education level, the discipline, and the application period of the STEM education to the experimental group, and the data of these variables were recorded in this section.

The data of the studies included in the scope of the study were coded by opening an Excel file and numbering the studies. In order to ensure the reliability of the data encoded in the research, the coding process was performed by the first coder having a doctorate in the field of curriculum instruction and education, and also by the second coder, being an expert in that field. After the coding process was completed, the compatibility between the coders was evaluated. Inter-encoder reliability calculation (consensus / (consensus + disagreement) x 100) (Miles & Huberman, 1994) and the reliability was found to be 96%. The validity of a meta-analysis study is proportional to the validity of the studies included in the study (Petitti, 2000). In this context, the validity findings of the studies included in the study were examined and an effort was made to ensure their validity. Additionally, studies using inappropriate data and research methods were not included in the meta-analysis and contributed to increasing their validity (Başol & Johanson, 2009).

Analysis of Data

The data analysis process includes the calculation of the effect size for each study, the control of publication bias, the heterogeneity test, and the calculation of the combined effect size. Comprehensive Meta-Analysis (CMA Version 3) program was used to analyze the data. Effect size is an analysis that shows the size and sensitivity of the experimental effect (Thalheimer & Cook, 2002). In meta-analysis studies, two different coefficient calculation

methods are used, "Cohen's d" and "Hedges's g" which are the standardized mean difference effect size indicators, but it is stated that both of them give similar results in the literature (Dinçer, 2014). On the other hand, since it is known that the 'Cohen's d' value is an indicator of effect size that should be used when the number of samples in each group is above 20 (Lipsey & Wilson, 2001), the analyzes in this study were performed by calculating the "Hedges's g" values. Specific classifications are used when interpreting the effect sizes obtained from the meta-analysis. Cohen's (1988) the classification of effect size is as follows: • 0–0.20 = weak effect • 0.21–0.50 = modest effect • 0.51–1.00 = moderate effect • >1.00 = strong effect.

Two different models are used in the calculation of effect sizes in meta-analysis. These are the fixed effects model and random-effects model. The researcher needs to determine in advance which model to act according to the analysis process (Dinçer, 2014). In order to make a more generalizable study and because it is a model recommended to be used in the field of social sciences (Cumming, 2012), this study was based on the random-effects model. On the other hand, meta-analysis aims to determine how the effect size varies across studies. In this respect, the random-effects model has a distribution of true effects. Regarding that the moderator effect can vary across studies, as well as the sampling variability, the random-effects size model was selected to match the expected heterogeneity in this meta-analysis.

RESULTS

Meta-Analysis Findings of the Studies Included in the Study

In meta-analysis studies, a general conclusion is drawn from the effect size of each study. In order to examine the effect of STEM education on the students' academic success, 64 studies were included in the meta-analysis process, and the effect size for all studies included in the meta-analysis was calculated. Findings regarding general effect size and heterogeneity were given in Table 2.

Table 2: Regarding the effect of STEM education on academic success

		95% Confidence Interval			**Test of Mean**		**Heterogeneity**	
Model	k	Effect Size	Lower	Upper	Z	p	Q	p
Fixed	64	0.766	0.714	0.817	29.197	.000	802.686	.000
Random	64	1.150	0.958	1.343	11.733	.000		

As seen in Table 2, heterogeneity test is significant (Q model= 802.686; df (Q) = 63; p= .000). On the other hand, I^2 value above 75% is an indicator of high heterogeneity (Higgins & Thompson, 2002), I^2 value can be interpreted that it is 92% highly heterogeneous (I^2= 92.151). The examination of the obtained data showed that the effect size was 0.766 by the fixed effect model, and the random effect model effect size was 1.150, and was significant (p=.00<0.5). The latter corresponds to a "large effect" value according to the effect size classification of Cohen et al. (2007). A forest plot of the studies demonstrating the distribution of effect size values calculated by the random effects model was shown in Figure 3.

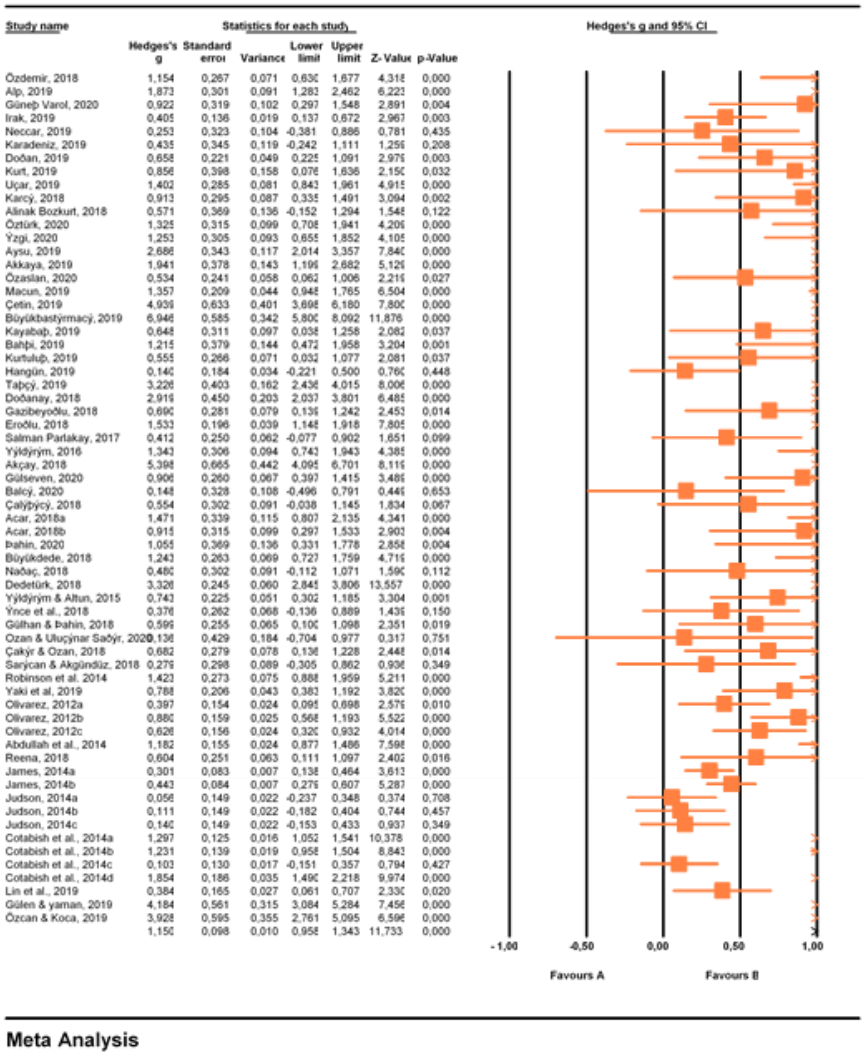

Figure 3. Forest plot demonstrating the distribution of effect size values

In the forest plot, the part determined with black vertical lines indicates the effect size of the relevant study in the meta-analysis, while the horizontal lines around it indicate that the effect size of that study is in the 95% confidence interval. In other words, the longer the horizontal line, the larger the confidence interval. According to the forest plot given in Figure 3, it is seen that the study with the largest confidence interval was attributed to Ozan and Uluçınar Sağır (2020), while the study with the smallest confidence interval was published by James (2014c).

When Figure 3 is examined in terms of effect sizes of the studies included in the meta-analysis, the study of the lowest effect size (g= 0.111) belongs to Judson (2014b), the largest belongs to (g= 6.946) Büyükbastırmacı (2019). While 41 studies (63.07%) have effect sizes below the average effect size, it is seen that 24 studies (36.92%) have a value above the average effect size of the study.

Publication Bias

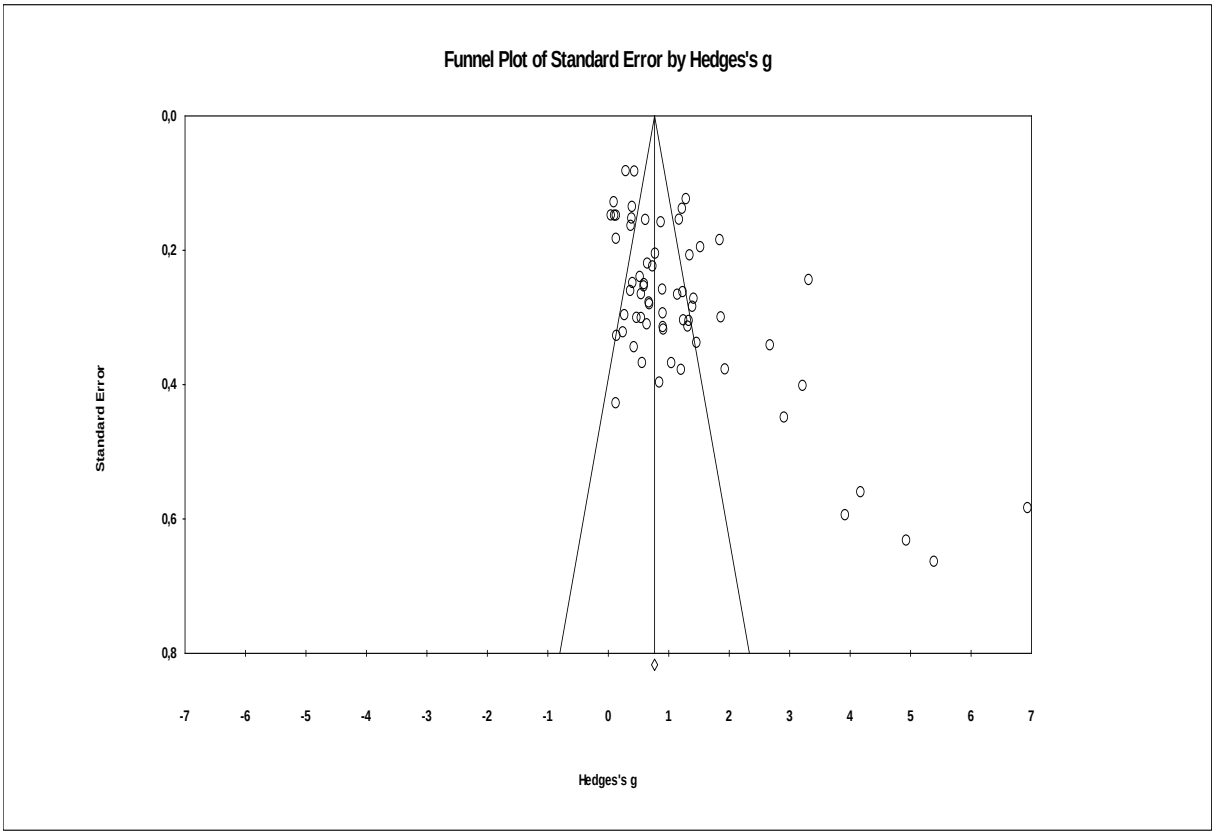

Figure 4. Funnel plot of standard error by effect size

Publication bias was evaluated using a funnel plot, the classic fail-safe N, and Orwin's fail-safe N. As shown in Figure 4, it was found that the funnel plot had a symmetrical distribution. Therefore, there was no publication bias in the present meta-analysis. The results of the classic fail-safe N indicated that 6115 missing studies would be needed to nullify the effect size, which was far larger than 330 (5k+10). Furthermore, the result of Orwin's fail-safe N revealed that 4747 missing studies would be needed to reduce Hedges's g to a trivial level (0.01). Therefore, the findings indicated that this meta-analysis was not affected by publication bias.

Findings Regarding Moderator Variables

Publication type, discipline, application period, and education level were determined as moderator variables to explain the founded heterogeneity. Moderating effect of these variables was given in Table 3.

Table 3: Analog ANOVA findings of the effect of STEM education on academic success according to the moderator variables

Moderator Variable	Heterogeneity between groups (Q_b)	p	K	Effect Size	Confidence Interval (95%)	Standard Error
Publication type						
National	7.229	0.007	47	1.1155	[0.904; 1.407]	0.18
International			17	0.083	[0.447; 0.918]	0.09
Discipline						
Science	21.394	0.000	47	1.156	[0.929; 1.383]	0.18
Mathematics			11	0.607	[0.324; 0.889]	0.11
Physics			3	1.140	[0.247; 2.033]	0.64
Other			3	0.290	[0.033; 0.612]	0.08
Application Period						
2-5 weeks	4.167	0.244	22	1.189	[0.794; 1.056]	0.33
6-9 weeks			20	0.830	[0.655; 0.845]	0.06
10-13 weeks			14	1.164	[0.665; 0.826]	0.23

14 weeks and above			8	0.832	[0.407; 0.661]	0.48
Education Level						
Primary school	1.929	0.587	7	1.055	[0.630; 1.481]	0.20
Secondary school			46	1.032	[0.808; 1.256]	0.17
High school			6	1.022	[0.541; 1.504]	0.23
University			5	0.749	[0.387; 1.111]	0.12

When Table 3 is examined, it is seen that 47 studies were national and 17 were international studies. Accordingly, there was a statistical difference between the effect sizes in the publication type (Q_b= 7.229, p= .00< .05). This difference is favored by national studies that have the highest effect size (g= 1.155). In other words, it was revealed that STEM education was found more effective on academic success in national studies. It is worth noting that national experimental studies that were carried out to investigate the effect of STEM education on academic success reached higher positive scores rather than international studies reached.

The effect of STEM education on the academic success were investigated on science in 47 studies, mathematics in 11 studies, physics in 3 studies, and other branches in 3 studies. Table 3 shows that there was a significant difference in the experimental group according to the discipline that the STEM education applied (Q_b= 21.394; p= .00 < .05). The meta-analysis shows that STEM education has a higher effect in the discipline of science (g= 1.156) than in mathematics (g= .607), physics (g= 1.140), and other disciplines (g= .290). Accordingly, it was interpreted that the effect size of STEM education on academic success differs with the difference in the discipline where the application is done.

The STEM education whose effect was to be measured was applied in 22 studies for 2-5 weeks, in 20 studies for 6-9 weeks, in 14 studies for 10-13 weeks, and also in 8 studies for 14 weeks, and above. Table 3 shows that while the highest effect size (g= 1.189) was performed between 2-5 weeks, the lowest effect size (g = 0.830) was performed for 6-9 weeks. However, the results in the Table 3 indicate that there was no significant difference according to the application period variable (Q_b= 4.167; p= 0.244 > .05). That is to say, the effect size of the STEM education on academic success doesn't differ according to the application periods of it to the experimental groups.

It is assumed that 7 studies were carried out at the primary school level, 46 studies at the secondary school level, 6 studies at high school, and 5 studies at university. The highest effect size is at the primary school level (g= 1.055), and the lowest effect size is at the university (g = 0.749). Accordingly, it can be said that there was no significant difference according to the education levels of the studies (Q_b = 1.929; p= 0.587> .05). Accordingly, it can be interpreted that the effect size of STEM education doesn't differ depending on the education level in which STEM education was applied.

DISCUSSION

Along with the developments in the 21st century, STEM education both aims to provide questioning, and learning by doing, and experiencing in the fields of science, technology, engineering, and mathematics, and to create an original product. In this way, students contribute not only to learning but also to the economic development of countries by understanding how to use this information (Gonzalez & Kuenzi, 2012). Furthermore, STEM education aims to raise a productive, scientifically literate society by adopting rapidly developing technological, and scientific changes (Bray, 2010).

STEM education is currently applied to increase the rate of students choosing professions in STEM fields, and also to increase their literacy in STEM fields, and to enable them to benefit from this information while solving problems in daily life (Thomasian, 2011). On the other hand, STEM education aims not only by using the disciplines of science, technology, mathematics, and engineering together, but also to acquire some skills called 21st century life skills which are generally being able to cooperate, communicate, think critically, and creatively (Yıldırım & Altun, 2014). Bybee (2010) stated that STEM education paves the way for having 21st century skills as being able to easily solve daily life problems encountered, having a different perspective, and analysis ability, and being more successful individuals. In order to keep up with the age's requirements, it is vital to acquire these skills, thus this emphasizes the importance of STEM education. For this reason, a lot of researches has been carried out on the STEM education recently, and different results have been acquired. That's the main reason why a meta-analysis study was needed in order to gather these results under a single roof, and show the big picture to readers, and researchers. This study aimed to determine the effect of STEM education on the academic success of students with the method of meta-analysis. In this context, 64 findings out of 56 studies that measure the effect of this education on student success with the experimental method and meet the criteria were included in the meta-analysis process. As a result of the analysis, the distribution of the studies included in the meta-analysis (Q value= 802.686, degrees of freedom= 63, p= .000) was found to be heterogeneous. On the other hand, since it is known that a value

of I^2 above 75% means that it is highly heterogeneous (Higgins & Thompson, 2002), I^2= 92.151, and 92% proved to be highly heterogeneous. Hence, this result confirmed that high heterogeneity of the effect size may come from the variety of the design, type, application period, assessment, population, and quality of the selected studies. As a result of the analysis, it was observed that only disciplines and publication type explained a significant degree of effect size heterogeneity among the moderator variables that were determined to explain the heterogeneity.

Based on the knowledge that it is more appropriate to use the random-effects model in the field of social sciences (Field, 2010), the findings in this study were interpreted accordingly. The average effect size of the studies included in the meta-analysis was g= 1.150; p =.00 was found, according to Cohen's (1988) classification, it was concluded that there was a large effect. In other words, STEM education has a high level of positive effect on students' academic success. Similarly, Ayverdi and Öz-Aydın (2020) conducted a meta-analysis with 38 studies which are on the effects of STEM education on learners' academic success, and reached a large effect. On the other hand, Yücelyiğit and Toker (2021) conducted a meta-analysis on STEM education on early childhood education, and they reached a moderate effect size. However, Saraç (2018) conducted a meta-analysis on 58 effect sizes, and reached a weak effect. It can be interpreted that the number of experimental studies in Turkey which are carried out to investigate the effect of STEM education on students' academic success increased recently, that's why the results of meta-analysis may vary. When meta-analysis studies conducted abroad on this subject are examined, Becker and Park (2011) reached an effect size of .63, D'Angelo et al. (2014) reported an effect size of .62, Belland et al. (2016) found an effect size of .46. Accordingly, it is possible to comment that national experimental studies that measure the effectiveness of STEM education on academic success has reached a positive effect. Regarding this comment, our present study is considered to contribute a more meticulous perception of the impact of this type of education on learners' achievement compared with the traditional learning approach.

Publication Type

Since a vast number of studies have been conducted to investigate the effectiveness of STEM education on academic success recently, publication type as national, and international studies was selected as a moderator variable to explain the founded heterogeneity. It was reached that there is a significant difference according to the publication type. In other words, the effect size of the STEM education on academic performance differs with the publication type of studies. The meta-analysis concluded that the effect size of STEM education on academic success differs according to the publication type in favor of national studies. Saraç (2018) and Ayverdi and Öz-Aydın (2020) conducted a meta-analysis on STEM education and reported the similar results with the present meta-analysis.

Discipline

The studies included in meta-analysis were conducted in STEM disciplines. These were science, mathematics, physics, and other disciplines. It is worth noting that since there was only one study carried out in some disciplines such as language, reading, art, these were categorized under the "other" group. It was concluded that STEM education has the highest effect size in the discipline of science. It was inferred that there is a significant difference according to the discipline to which the STEM education was adopted. In other words, the effect size of the STEM education on academic success differs with the discipline that the STEM education was used. The present study confirmed that the discipline of science has high effect size and this result is supported by the findings of Saraç (2018). Similarly, Becker and Park (2011) reported that the highest effect sizes belonged to mathematics and science achievement. When it is considered that the studies on STEM education were carried out in science classes (Cotabish et al., 2014; Gülhan & Şahin, 2018; Gülseven, 2020; Olivarez, 2012; Ozan & Uluçınar Sağır, 2020; Reena, 2018; Sarıcan & Akgündüz, 2018), this can be interpreted as an expected result. In this respect, it is possible to comment that experimental studies that measure the effect of the STEM education on science achievement have reported a positive effect. Our present study is considered to contribute a more meticulous perception of the impact of this type of education on learners' science achievement compared with the traditional learning approach.

Intervention

In this meta-analysis study on the effect of STEM education on academic success, the duration of applying the education to the experimental group was determined as another moderator variable. It was understood that there was no significant difference according to the duration of intervention. In other words, the duration of applying the model to the experimental group did not affect the average effect size. Moreover, the present study revealed that the short intervention duration (2-5 weeks) produced the largest effect size. Siregar et al. (2020) reached a similar result in their meta-analysis by confirming that short term intervention has the highest effect size rather than long term.

Education Level

The studies included in the meta-analysis consisted of studies conducted at primary, secondary, high school, and

university levels. However, no significant difference was reached, and it was concluded that the teaching level could not explain the effect of STEM education on academic achievement. Similarly, Siregar et al. (2020) determined the teaching level as the moderator variable in their meta-analysis, the findings of this study supports this result. In contrast with the present meta-analysis, Belland et al. (2017) determined education level as a moderator variable, and reach a significant difference in favor of adult learners whereas Becker and Park (2011), Ayverdi and Öz-Aydın (2020), and Saraç (2018) reported a significant difference in favor of young learners. The present meta-analysis shows that the highest effect size belongs to primary and secondary school level however significant difference could not be reached.

CONCLUSIONS AND IMPLICATIONS

To conclude, STEM education has the vital importance to be applied in order to raise individuals having 21st century skills. With the advancement of science and technology, it is expected to raise individuals with these skills such as creativity, critical reasoning, research and questioning, cooperation and problem solving. Today's century expects students to be productive and problem-solving individuals. STEM education has emerged on the education scene because it provides these competencies and approaches problems with a totalitarian perspective (Bybee, 2010). STEM education is universal; focuses on literacy skills such as creative thinking, critical thinking, problem solving, and collaborative work. It is essential that these skills are acquired by the individual. STEM education paves the way for being creative, productive, thinking critically, and analytically in the field of science, technology, engineering, and mathematics. This situation creates a need to examine the research findings based on the effects of STEM education on academic success. These findings are very promising and provide insight into the implementation of the STEM education in the future. This study concluded by the large effect size according to Cohen's classification. On the other hand, it is understood that the effect size differs with the discipline in favor of science. Consequently, this paper emphasized that STEM education paves the way for academic achievement especially in science. It is considered that this study contributes to the literature and sheds light for researchers and readers to apply STEM education especially in science education.

In the light of the findings obtained at the end of the research, it was seen that the effect size of the STEM education on the academic success of the students was at a high level. In line with the results obtained, it was deemed appropriate to make the following suggestions:

- As a result of the analysis, it was understood that STEM education had a large effect on the academic success of the students. For this reason, the use of STEM education in educational environments should be encouraged, and the necessary infrastructure, and facilities should be provided.
- In order to encourage meta-analysis studies, and reach reliable results, researchers may be advised to clearly write values such as mean, standard deviation, and sample size in their studies.
- It was understood that the discipline was a distinctive variable on academic success of the STEM education. It was found that studies applied to the disciplines of science had higher effect sizes. For this reason, it can be suggested that the application of STEM education in especially science classes should be encouraged.
- This meta-analysis study focuses on publication type, education level, application period, and discipline as moderator variables. Future studies can focus on different aspects.

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NOTE: References marked with '*'indicate studies included in meta–analysis.