International Journal of Progressive Education, Volume 18 Number 2, 2022

The Effect of STEM Education Integrated into Teaching-Learning Approaches (SEITLA) on Learning Outcomes: A Meta-Analysis Study

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Abstract

STEM education is an educational approach whose popularity has increased in recent years. Although numerous efforts have been made to make STEM education more effective, educators face great difficulties in finding appropriate teaching methods and strategies. Within this framework, the aim of this research is to examine the results of studies that investigate the effect of STEM education integrated into teaching-learning approaches (SEITLA) on learning outcomes and to evaluate the results obtained from these studies. For this purpose, the meta-analysis method was used in this study. In line with the aim of the study, 33 experimental studies made between the years 2015-2021 were included in the meta-analysis, and the effect sizes of these studies were calculated. It was found that the effect of these activities on individuals' learning outcomes had an effect size ranging between 0.13 and 2.09. As a result of the meta-analysis, it was determined that among the studies examined in the research, the effect of STEM education carried out with a mastery learning approach on students' learning outcomes was considerably large. Another interesting result determined in the study was that the effect of a technology-supported STEM approach on learning outcomes was very small. In conclusion, STEM education integrated into teaching-learning approaches such as mastery learning, evidence-based education, and blended learning can be more effective on students' learning outcomes. At the end of the study, discussions related to the findings are also included.

Keywords: Teaching Approaches, Learning Approaches, STEM, Meta-Analysis, Learning Outcomes

DOI: 10.29329/ijpe.2022.431.8

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INTRODUCTION

More effective STEM? Why shouldn't there be?

STEM (formed from the words Science, Technology, Engineering and Mathematics) education is an educational approach whose popularity has increased in recent years. STEM education is student-centred, encourages the designing of products, and guides the development of research and inquiry skills (Büyükdede, 2018). While Moore (2009) specified the aim of STEM education as the training of individuals who are equipped to meet the workforce needs of the 21st century, Bybee (2010) expressed it as developing in-depth understanding related to STEM areas and achieving development towards technology. STEM can be taught in four different ways, as independent subjects, by emphasising one or two subjects, by integrating one STEM discipline into the other three, or by mingling the four disciplines with each other (Dugger, 2010). Moreover, it is not always necessary to involve all four disciplines at the same time (Stohlmann, Moore & Roehrig, 2012).

STEM education is discussed under two headings, namely Traditional STEM Education and Integrated STEM Education (Guzey, Harwell & Moore, 2014; Sanders, 2009; Thomas & Williams, 2009). While Traditional STEM Education is an approach which recommends that the STEM disciplines should be dealt with separately and gives prominence mostly to science and mathematics (Bybee, 2010; Hoachlander & Yanofsky, 2011; Sanders, 2009), Integrated STEM Education places emphasis on teaching science, mathematics, technology and engineering practices by integrating them with each other (Burrows, Lockwood, Borowczak, Janak & Barber, 2018). In the literature related to STEM education, some researchers lay stress on the combination of two or more disciplines (Kelley & Knowles, 2016; Nadelson & Seifert, 2017), while others stress that learning should be carried out by combining all four disciplines (Burrows, Lockwood, Borowczak, Janak & Barber, 2018). Since instruction by means of integrated programmes, in which all the science, technology, engineering and mathematics disciplines of STEM education are emphasised, is not possible due to the structure of schools and curricula, this education is carried out by including technology and engineering in the subjects of science and mathematics that are included in these curricula (Bybee, 2010). According to Çorlu, Capraro and Capraro (2014), STEM is defined as integrating special knowledge and skills belonging to one discipline, which is taken as the basis, with at least one other STEM discipline, in line with students' interests. STEM education, which aims to foster knowledge, skills, literacy and examination of problems from an interdisciplinary perspective in individuals, and to enable students to prepare for 21st century developments and to acquire 21st century skills, provides students at all levels with opportunities to master the disciplines of science, technology, engineering and mathematics Meyrick, 2011), enables students to better prepare for STEM careers (Brown, Brown, Reardon & Merrill, 2011), and leads to an increase in students' academic achievement (Bybee, 2010; Çevik & Abdioğlu, 2018; Guzey, Moore, Harwell & Moreno, 2016). The fact that STEM education gives students one of the best opportunities to experience learning in a real-world situation can be given as a reason for this (Wang, 2012).

Integration of STEM into teaching-learning approaches (SEITLA)

To ensure that the learning outcomes in STEM education are at the desired level, a great deal of responsibility falls upon the educators who have the role of STEM implementers. It is not sufficient for the educators who are to conduct STEM education to possess only subject matter knowledge (Çorlu, Capraro & Capraro, 2014). Besides subject matter knowledge, teachers need to possess teaching knowledge and skills. Despite a number of efforts to make STEM education more effective, educators are faced with great difficulties in finding appropriate teaching methods and strategies. There is not only a lack of knowledge in many educators; at the same time, they are not aware of effective teaching strategies, either. Yet educators can integrate STEM education into different teaching-learning approaches. The teaching-learning approaches that are frequently used in STEM studies emerge as the project-based approach (Craig, & Marshall, 2019; Çevik, 2018), the design-based approach (Dedetürk, Saylan Kırmızıgül & Kaya, 2019; Savran Gencer, Doğan & Bilen, 2020), the 5E instructional model (Büyükdede & Tanel, 2019), computer-based learning (Dasgupta, Magana

& Vieira, 2019), and problem-based learning (Duran & Şendağ, 2012; Ergün & Balçın, 2019). Besides these, flipped learning (Eichler & Peeples, 2015), blended learning, technology-enhanced learning (Chien, 2016), the 7E instructional model (Güven, Selvi & Benzer, 2018), Toulmin's argument model (Bahşi, Açıkgül & Fırat, 2020; Gülen & Yaman, 2019), web-based learning (Ayaz, Gülen & Gök, 2020), mastery learning (Groen et al., 2015; Chang & Chen, 2020), hands-on learning (Cloutier, Dwyer & Sherrod, 2016), evidence-based learning (Levin & Tsybulsky, 2017; Miller et al., 2017; Milner-Bolotin, 2017; Milner-Bolotin, 2018; Stains et al., 2018), and game-based learning (Vu & Feinstein, 2017) are also teaching-learning approaches used in STEM education. A review of the literature reveals that there are many studies reporting that SEITLA practices are effective on students' learning outcomes (Bender, 2016; Çevik, 2020; Han, Capraro & Capraro, 2014; Roberts, 2013; Smith, Douglas, & Cox, 2009, Sutaphan & Yuengyong, 2018; Williams, 2019). On the other hand, there are also studies in the field which have reached the exact opposite conclusion (Geiger et al., 2008; Hansen, 2014; Judson, 2014; Wiswall, Stiefel, Schwartz & Boccardo, 2014). In this context, this study is important in terms of revealing that while the use of STEM education with some teaching-learning approaches encourages learning in individuals, there may be no effect of using STEM education together with other approaches.

Goals of the current meta-analysis

Although there are meta-analysis studies related to STEM education, there is no meta-analysis study related to the general effect of SEITLA on learning outcomes. It is hoped that the holistic evaluation of the results of studies related to the effect of SEITLA on learning outcomes in this study will contribute to the literature. The sub-problems determined in line with this aim are as follows:

- What are the effect sizes of experimental studies investigating the effect of SEITLA on learning outcomes?

- What are the effect sizes of experimental studies investigating the effect of SEITLA on learning outcomes according to the teaching-learning approach that is used?

METHODS

Data sources and search strategy

In the study, the reference-searching procedure suggested by Cooper (2010) for collecting references related to the IASE was observed. In this research, in order to access comprehensive and adequate literature of the IASE, published journal articles and unpublished conference papers for the period 2015-2021 were screened. This period was selected because it is seen in the literature that since 2015, teaching-learning approaches and STEM have started to be used together, and that research on this subject has been increasing rapidly during the last 6 years. To access the related literature, electronic searches, manual searches and a manual reference list check were carried out. Due to the authors' limited linguistic competence, only material written in English was chosen. The databases used for electronic searches were the Web of Science (WoS), Education Resources Information Center (ERIC/EBSCO), SCOPUS (A&I), Elsevier, Google Scholar, ULAKBIM (Turkish Journal Database), Wiley Online Library Full Collection, Taylor & Francis Online, Science Direct and Springer Link databases. Previous meta-analysis studies related to STEM were also examined (e.g., Batdi, Talan & Semerci, 2019; Becker & Park, 2011; Khoiri, 2019; Li, Wang, Xiaoand & Froyd, 2020; Mustafa, Ismail, Tasir, Said & Haruzuan, 2016). Based on the basic concepts and keywords of STEM, the two keyword groups given below, and combinations of these, were used to carry out the searches: (1) STEM, STEM approach, STEM education, integrated STEM, integrative, implementation; (2) Teaching and learning approaches in STEM, effect learning in STEM, effect teaching in STEM, academic achievement, learning outcome, subject. The two keyword groups were integrated with Boolean operators (Cooper, 2010) especially by using the "or" operator within sets and the "and" operator between sets.

After all the relevant literature had been collected, in order to try to find studies that had been missed but were relevant, a further type of research was made by using the reference lists found in the literature. In the second type of research, which was made by the two researchers, great care was taken not to miss any publication.

Search results

The initial screening stage

In the literature screening, 68 journal articles related to the IASE (ULAKBİM=2 ERIC-EBSCO=20, Elsevier=1, Google Scholar=24, SCOPUS=5, Web of Science=15, and Wiley=1) published between the years 2015-2021 were identified. The two authors read the abstracts of each article, and then decided whether the article was related to the effect of SEITLA on students' learning outcomes or not; as a result, in this first screening process, 24 articles were selected.

Screening for experimental and quasi-experimental studies in the context of learning outcomes

At the second stage, studies included in the first stage were further screened according to the research method used. Only experimental studies using designs involving pretest-posttest equivalent groups, posttest-only equivalent groups, randomly paired subjects and posttest-only control groups, and pretest-posttest non-equivalent groups and counterbalanced designs (Ary, Jacobs & Razavieh, 2002) were included. Conceptual analysis of research investigations, case studies and qualitative research, questionnaire research and pre-experimental studies were excluded at this stage. Following this second-stage screening, 17 further articles were identified, and both authors concurred that 9 of these were suitable for the meta-analysis.

Screening for inclusion in/exclusion from the meta-analysis

Within the scope of the research, to determine whether a study was to be included in the meta-analysis, the following three criteria were used:

1. SEITLA practices formed the main variable of the study. In experimental groups, the effects of SEITLA on learning outcomes in individuals were compared with control groups using traditional learning (paper-based or with desktop computers). Experimental studies with control groups purely using a STEM approach other than SEITLA were excluded.

2. In the studies, it was seen that means, standard deviations, t or F values, variance and number of people in each group were sufficient to calculate effect sizes. Studies in which sample sizes of each group were not provided according to Lipsey and Wilson (2001), in which there were no inferential statistical results, or in which there were insufficient inferential statistical results to calculate effect size were excluded.

3. The experimental results are presented according to the learning performance category; this category is learning achievement measured with standardised tests or tests created by the researchers.

Selection and coding of variables

Three main elements were also taken into account in the coding. The research name, the practices in the research (SEITLA) and the research results are the dependent variables.

Research name

This section states the name of the first author and the publication year and article title.

Treatments

The treatment of the examined articles was in the direction of the teaching-learning approaches and experimental study used in the articles in the “context” component.

For this study, the researchers coded 33 articles according to this framework. Missing values were coded as 0, the coding process was based on the procedure suggested by Cooper (2010), and the two researchers (coders) reached a consensus on the definitions of the entries and the variables related to these by first choosing and discussing two example articles. Secondly, the coders coded 5 articles independently, discussed the differences in the coding results and negotiated for a consensus. Finally, in line with the common concept achieved, the coders coded all the remaining articles, discussed the differences in the codes, and negotiated until a consensus had been reached on all codes. For the coding, Comprehensive Meta-Analysis (CMA) (Borenstein, Hedges, Higgins & Rothstein, 2005) software was used.

Data analysis

Calculating effect sizes

The following steps of meta-analysis suggested by Borenstein, Hedges, Higgins and Rothstein (2009) were used: (a) determine the effect sizes of each article, (b) calculate the weighted mean effect sizes between the articles, (c) calculate the confidence interval for the mean effect size, and (d) determine whether or not the effect size of any specific group is affected with a moderating variable based on heterogeneity analysis (using the test statistic QB). Two formulae were used to calculate the effect sizes of the study results. For random assignment experimental studies and experimental studies without pretests, Cohen’s d was used to determine effect sizes (Lipsey & Wilson, 2001, p. 48). For experimental or quasi-experimental studies with pretests, it is recommended that the pretest rather than the posttest is taken into consideration in order to reduce potential selection bias (Furtak, Seidel, Iverson & Briggs, 2012). Therefore, the formula used by Furtak et al. (2012, p. 311) was used to obtain the effect sizes for studies with pre- and posttests. Both types of effect size were adjusted using sample weights to calculate Hedge’s g (Lipsey & Wilson, 2001, p. 49).

Statistical Model Selection

In meta-analysis, if the samples are the same size, a fixed effects model is selected, whereas if the samples are different sizes, a random effects model is chosen. For the selection of the statistical model, the decision is made according to the p and Q values obtained as a result of the heterogeneity test. The size of the p value is examined according to 0.05, or the size of the Q value is examined according to the df value in the chi-square table. If $p>0.05$ or $Q<df$, then it can be said that the studies that form the meta-analysis do not have a similar structure and are heterogeneous. In this case, it is concluded that the selection of the statistical model in the analysis should be based on a random effects model. In line with the information obtained, according to the analyses made in this study, it was considered appropriate to base the selection of statistical model on a random effects model.

Reliability and Validity of the Study

In order to reveal that the conducted meta-analysis study was reliable and valid, and to determine the publication bias, Rosenthal’s fail-safe N method and Orwin’s fail-safe N method were used. The data obtained from Rosenthal’s fail-safe number, which is a test performed to determine study bias, are presented in Table 1.

Table 1. Rosenthal's fail-safe number data

Z value for examined studies	23.86
p value for examined studies	0.000*
Alpha	0.050
Direction	2
Z value for alpha	1.95996
Number of studies examined	33
Fail-safe number (FSN)	4858

*p<.05

As shown in Table 1, for Rosenthal's fail-safe number data, the Z value for the examined studies is 23.86, the p value for the examined studies is 0.000*, the alpha is 0.050, the direction is 2, the Z value for the alpha is 1.95996, the number of studies examined is 33, and the fail-safe number is 4858. For *p<0.05, in other words, for the significance of the meta-analysis result to disappear, 4858 studies having an effect size value of 0 need to be made. In other words, for the findings of this meta-analysis consisting of the data of 33 studies to be invalid, there need to be at least 4858 studies in the literature with opposite values to the findings in hand. Similarly, Orwin's method was also used to determine publication bias in the study, and similar findings were made to Rosenthal's fail-safe analysis. These findings are given in Table 2.

Table 2. Orwin's fail-safe number analysis

Hedge's g in examined studies	0.596
Criterion for a "trivial" Hedge's g	0.000
Mean Hedge's g for missing studies	0.000
Number of missing studies required to take Hedge's g value below 0.1	118

According to Orwin's method, the mean effect size obtained as a result of this meta-analysis was found to be 0.596, while the number of studies required to be included in the meta-analysis was found to be 118. For the 0.596 mean effect size found in the meta-analysis to decrease to a value of 0.000, and for the general effect size values to be evaluated as trivial, 118 studies with an effect size value of zero need to be made. However, the 33 studies included in the meta-analysis constitute the total of the studies which were able to meet the inclusion criteria from all the studies (qualitative, quantitative, theoretical, etc.) conducted in Turkey related to this research question. In this case, it can be stated that there is no publication bias resulting from the meta-analysis. To sum up, when the fail-safe numbers obtained with both methods are examined, it can be said that this meta-analysis study is reliable.

Evaluating publication bias

Rosenthal's (1979) fail-safe N (that is, the classic fail-safe N) was used to estimate how many trivial effect sizes (unpublished data) would be required to reduce the general effect size to a trivial level. The comparison criterion was 5n + 10 (here, n is the number of studies included in the meta-analysis). If the fail-safe N is greater than 5n + 10, it is not possible for the estimated effect size of the unpublished studies to affect the effect size of the meta-analysis. Moreover, to estimate the number of missing null studies required to bring the size of effect of the theme to a trivial level, Orwin's fail-safe N (1983) was also adopted.

RESULTS AND DISCUSSION

Descriptive information

Table 3. Categories of 33 articles published between 2015-2021

Learning and teaching approach/model	Number of studies	Number of effect sizes	Percentage of studies (%)
Project-based Learning	11	1931	33.33
Design-based Learning	4	432	12.12
5E Instructional Model	3	119	9.09
Computer-based Learning	3	342	9.09
Problem-based Learning	2	79	6.06
Flipped Learning	1	37	3.03
Blended Learning	1	129	3.03
Technology-enhanced Learning	1	30	3.03
7E Instructional Model	1	30	3.03
Toulmin's Argument Model	1	40	3.03
Web-based Learning	1	169	3.03
Mastery Learning	1	58	3.03
Hands-on Learning	1	50	3.03
Evidence-based Learning	1	44	3.03
Game-based Learning	1	332	3.03
Total	33	3822	100

Table 3 shows the distribution of the approaches/models included in SEITLA and the percentages equivalent to these. There are 3822 participants in a total of 33 articles. Among the teaching-learning approaches, the most studies in which the STEM approach was included were conducted with a project-based learning approach (33.3%), followed by studies conducted with a design-based learning approach (12.12%). Next come the 5E instructional model (9.09%), computer-based learning (9.09%), and problem-based learning (6.06%), respectively.

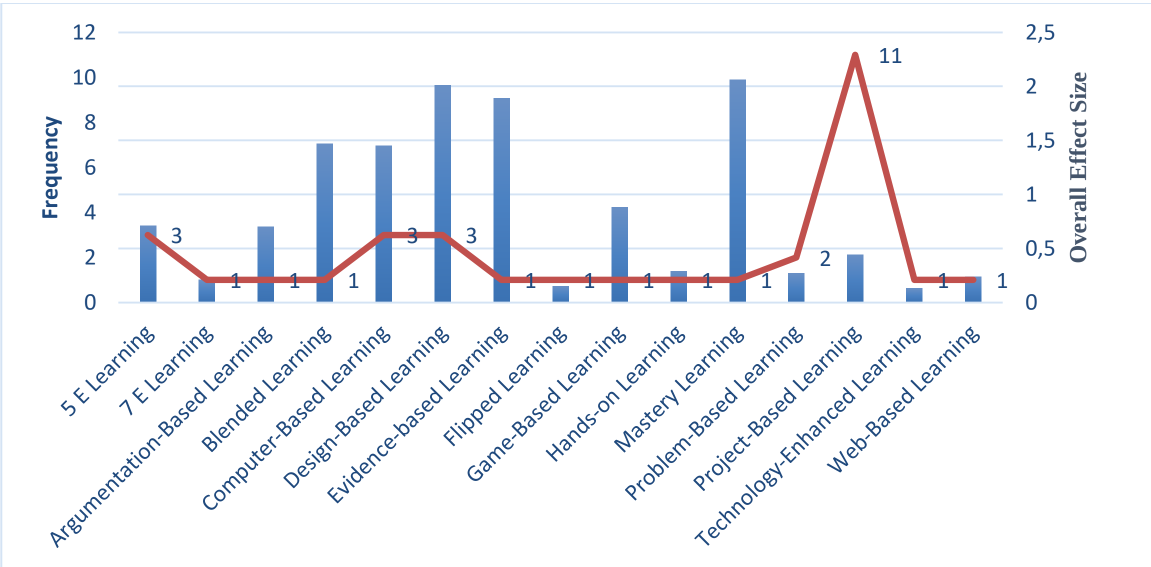

Fig. 1. Histogram of the effect sizes for the 33 articles included in this meta-analysis.

Table 4. Effect Sizes and Heterogeneity Test

Model	n	Mean Effect Size	Z	Standard Error	95% Confidence Interval		sd	Q	p	I^2	Variance
					Lower Limit	Upper Limit					
Fixed Effects Model	33	0.60	21.24	0.02	0.54	0.65	32	424.61	.000	92.46	0.02
Random Effects Model	33	0.88	8.05	0.11	0.66	1.09					

Tests for heterogeneity:

Q statistic: since the threshold value according to the chi-square table with a degree of freedom of 32 is 46.194 and the value calculated by CMA is 424.61, then we can say there is heterogeneity, since 424.61>46.194. Moreover, the fact that the I^2 value (92.46) is over 75 reveals that there is a high level of heterogeneity.

Since the mean effect size is 0.88, it is seen that this value shows a large effect according to Cohen.

Table 5. Analysis of sub-groups in Random Effects Model

Variable		N	Effect Size (g)	S.E.	V	95% Confidence Interval		Q	Z	p
						Lower Limit	Upper Limit			
Teaching-Learning Approaches	5 E Instruction	3	0.73	0.14	0.02	0.45	1.01	2.10	5.13	.00**
	7 E Instruction	1	0.22	0.36	0.13	-0.49	0.93	0.00	0.60	.49
	Argumentation-based Learning	1	0.72	0.32	0.10	0.08	1.36	0.00	2.20	.02*
	Blended Learning	1	1.48	0.19	0.04	1.09	1.87	0.00	7.47	.00**
	Computer-based Learning	3	1.46	0.11	0.01	1.24	1.68	13.07	12.81	.00**
	Design-based Learning	4	1.27	0.10	0.01	1.07	1.47	108.64	12.46	.00**
	Evidence-based Learning	1	1.94	0.45	0.20	1.06	2.83	0.00	4.31	.00**
	Flipped Learning	1	0.15	0.34	0.11	-0.51	0.83	0.00	0.45	.64
	Game-based Learning	1	0.88	0.11	0.01	0.65	1.11	0.00	7.68	.00**
	Hands-on Learning	1	0.30	0.14	0.02	0.01	0.58	0.00	2.08	.03*
	Mastery Learning	1	2.09	0.36	0.13	1.39	2.80	0.00	5.82	.00**
	Problem-based Learning	2	0.27	0.17	0.03	-0.06	0.62	1.21	1.58	.11
	Project-based Learning	11	0.44	0.04	0.00	0.36	0.52	94.01	11.00	.00**
	Technology-enhanced learning	1	0.13	0.18	0.03	-0.22	0.49	0.00	0.74	.45
	Web-based Learning	1	0.24	0.07	0.00	0.08	0.39	0.00	3.09	.00**

*p < 0.05; **p < 0.01

The effect sizes on learning achievement in students was examined in different studies in which SEITLA was used. According to Table 5, it was determined that the study in which STEM was used together with a mastery learning approach had the largest effect size on learning achievement (g ¼ 2.09, p <0.01), followed by evidence-based learning (g ¼ 1.94, p <0.01), blended learning (g ¼ 1.48, p <0.01), and computer-based learning (g ¼ 1.46, p <0.01), respectively. The effect size on learning achievement of studies in which STEM education was carried out with 7E instruction, flipped learning, problem-based learning and technology-enhanced learning was not significant.

CONCLUSION

Despite numerous efforts to make STEM education more effective, educators face great difficulties in finding suitable teaching strategies. Many educators not only lack knowledge, but they are also unaware of effective teaching strategies. In the light of this, the meta-analysis study that we have carried out is concerned with studies in which SEITLA and its effects on individuals' learning outcomes were tested. In this context, it provides concrete evidence as a study that will guide future research on SEITLA. Accordingly, in 33 experimental studies made between the years 2015-2021, these activities had effect sizes ranging between 0.13 and 2.09 on individuals' learning outcomes. The fact that the mean effect size of the study is 0.88 is evidence that this value shows a large effect according to Cohen. When the literature is reviewed, it is seen that there are numerous studies reporting that studies in which SEITLA is used are very effective on students' learning outcomes (Bender, 2016; Çevik, 2020; Han, Capraro & Capraro, 2014; Roberts, 2013; Smith, Douglas, & Cox, 2009, Sutaphan & Yuengyong, 2018; Williams, 2019). This study is important in terms of revealing that while the use of STEM education with some teaching-learning approaches encourages learning in individuals, the use of STEM education with other approaches may not be effective.

Among the studies examined in the research, it was determined that STEM education conducted with a mastery approach had a very large effect on students' learning outcomes (g=2.09). The fact that in the studies by Groen et al. (2015), Yıldırım (2017), and Chang and Chen (2020), in which STEM education was used together with mastery learning, it was emphasised that individuals' learning was greater and more effective, corresponds with the findings of this study. It was determined that in the 33 experimental articles that were identified, approaches such as project-based learning, design-based learning, the 5E instructional model, and problem-based learning were mostly used with the STEM approach. This finding corresponds with a number of studies in the literature (Çevik, 2020; Mustafa, Ismail, Tasir, Said & Haruzuan, 2016; National Academy of Sciences, 2014; Williams, 2019). The mastery learning theory is grounded on the belief that all children can learn when suitable conditions for learning are provided. Teaching strategies related to mastery learning are designed to put this belief into practice in modern classrooms (Guskey & Gates, 1986). Current implementations of mastery learning are generally based on Bloom's (1968) mastery learning model. We can say that certain fine points affecting students' achievement in STEM correspond exactly to the three main variables of this model, namely a) the degree to which the required prerequisite learning/acquisition has been realised for the targeted skills=student characteristics; b) the degree of devotion to and participation in instruction=instruction; c) the degree of compatibility with the instructional need in practice=learning products (Bloom, 1995). STEM is student-centred, encourages the designing of products, and guides the development of research and inquiry skills (Büyükdede 2018). It would be appropriate to mention three stages while implementing STEM education in the mastery model. In the first stage, deficiencies in preliminary learning are determined prior to concept instruction related to the first discipline at hand. Then, the deficient knowledge is remedied. After this, the new concept is taught. After the topic has been taught, an assessment test is implemented. Following the assessment test, once the student's success is at the desired level, at the second stage, teaching of the next discipline is begun. A similar procedure is followed in the second discipline. At the third stage, a problem situation from daily life is given, a product is produced by carrying out engineering design processes, and the lesson is ended (Yıldırım, 2020). In this context, it can be said that STEM education integrated into an instruction process carried out in a mastery learning model will have a large impact on students' achievement. Another effective teaching-learning approach into which STEM education is integrated is the evidence-based learning approach. In the literature, the appeal of the evidence-based learning approach was welcomed by a number of STEM educators (Levin & Tsybulsky, 2017; Miller et al., 2017; Milner-Bolotin, 2017; Milner-Bolotin, 2018; Stains et al., 2018). The importance of the use of the evidence-based learning approach in enabling students to learn from past experiences and influence the future is stressed especially in training STEM teachers or preservice teachers.

Another interesting finding revealed in the study was that a technology-supported STEM approach had a very small effect on learning outcomes (g= 0.13). It is expected that technology learning activities used in a STEM approach that has engineering design at its centre will be beneficial for implementing STEM education. Yet in studies related to technology-supported engineering design -such as STEM- the cognitive structures of expert practitioners in engineering design (Atman et. al., 2007) and the characterisation of the engineering design process (Hannah, Joshi & Summers, 2012) are important. If educators are to implement a technology-supported STEM education, their own cognitive structures related to engineering design are also of great importance (Lin, Wu Hsu et al., 2020). Mayo (2009) reported that in technology-supported STEM activities such as video games, the quality of the games affected the quality of instruction. Yet D'Angelo et al. (2013) argued that although technology-supported STEM education generally had positive effects, there was still much to be learnt about the educational benefits of computer simulations in STEM areas. To make STEM education more productive, the use of education technologies such as online interactive learning environments, digital games, augmented reality (AR) and robots must be one of the important issues for researchers in the field of STEM education and education technology. Yet the fact that some teaching-learning approaches are inadequate in fostering the use of engineering design skills that lie at the heart of STEM may also cause them to lack a significant effect on learning outcomes. For example, it can be said that STEM education integrated into design-based learning, which was accessed within the scope of the study, has a high effect value because it is a type of project-based learning that deals with significant real-world problems and facilitates content learning by giving students an opportunity (Becker & Park, 2011; English & King, 2015).

Using a STEM activity together with an effective teaching-learning approach in class or out of class can have an impact on students' learning outcomes. A STEM activity integrated especially with teaching-learning approaches like mastery learning, evidence-based learning and blended learning can be more effective. Moreover, STEM education with project-based, problem-based or 5E learning approaches can be effective on learning outcomes. In STEM activities in which the intensive use of technology is planned, teacher competencies and readiness of infrastructure are of great importance. It can be recommended that STEM education, in which learning by doing and experiencing is taken as the basis, should be used together with teaching-learning approaches in which students can use all their senses and are more at the centre, and in which the teacher can serve strictly as a guide and direct the students. Again, while selecting the teaching-learning approaches into which STEM education is to be integrated, selection by also giving consideration to the curriculum, the students' readiness levels, the school administration and parents' situations will change the productivity of education in a positive direction.

Limitations

The study has certain limitations. The research findings are limited to 33 studies that meet the inclusion criterion. Another limitation of the research is the fact that the data for the integrated STEM education and learning outcomes in the examined studies were collected with self-reported measurement tools. The studies included in the research are built on an experimental model, and include STEM education integrated into a teaching-learning approach. In the studies included in the research, a standard for the study groups was not sought.

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