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A meta-analysis on the effectiveness of the stem approach on students' mathematical creative thinking ability

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Abstract

Studies on the effectiveness of STEM implementation in Mathematics learning, especially in mathematical creative thinking ability carried out by previous researchers, are interesting to be studied. However, several studies have shown different results that can lead to different interpretations. This study aims to estimate dan examine the effectiveness of STEM on students' mathematical creative thinking ability from the relevant studies. This study analyzed 12 primary studies from various electronic search engines within the year of publication from 2017 to 2022. All primary studies in this research were analyzed using the meta-analysis with Comprehensive Meta-Analysis 3.0 (CMA 3.0) software by selecting the formula of Hedge to determine its effect size. The results of this meta-analysis study indicated that the STEM approach was effective for students' mathematical creative thinking abilities with an effect size of 0,935 in the category of high effect. There were differences in the effect size of the STEM approach on students' mathematical creative thinking abilities regarding STEM integration with learning models and educational levels. This means that the type of integration of the STEM approach with the learning model and educational level significantly causes heterogeneity in students' mathematical creative thinking abilities. The results of this study are expected to provide educators with an overview of how STEM can be applied in mathematics learning, especially in improving mathematical creative thinking ability.

INTRODUCTION

Mathematical creative thinking ability is important in mathematics learning (Rahmawati et al., 2022). Students need to improve their creative thinking ability so that the learning process will be better and more enjoyable. This must be done to overcome classic problems in learning mathematics about students' difficulties in understanding mathematics. It is undeniable that Mathematics is considered one of the most difficult subjects to learn (Hidayat & Rahmi, 2022; Kholil & Safianti, 2019; Siregar, 2017). The number of formulas, rules, and symbols in mathematics is often considered one of the causes of difficulties in learning mathematics, and sometimes it even becomes boring. Teachers must be able to teach creatively so that it is easier for students to understand mathematics as a science that can be applied to other sciences following today's increasingly rapid technological developments.

Creative thinking is the ability to see a problem from various perspectives (Meika & Sujana, 2017). Creative thinking allows students to create new ideas and solve problems from a different perspectives (Sakinah & Widodo, 2019). Also, it allows students to produce various ideas and solve problems with various possible solutions. The STEM (Science, Technology, Engineering, and Mathematics) approach in mathematics learning allows teachers to connect mathematics to other subjects, such as science, technology, and engineering.

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Research on the implementation of STEM in mathematics learning, especially research on the effect of the STEM approach on mathematical creative thinking ability, has been carried out by previous researchers. However, several studies concluded different results. For example, research by Amiruddin & Juwairiyah (2019) concluded that STEM has a large effect on students' mathematical creative thinking ability, while research by Jawad et al. (2021) concluded that STEM has a moderate effect on students' mathematical creative thinking ability. Other research concluded that STEM only has a small effect (Noviyani, 2022). This heterogeneity of the results can lead to a problem for teachers who want to implement STEM in their learning activities. On the other hand, educators or teachers need to obtain comprehensive information about the effectiveness of the STEM approach in Mathematics learning. Therefore, further research is needed to summarize, integrate, estimate, and evaluate the effectiveness of the STEM approach in Mathematics learning from these relevant studies.

Previous research summarized STEM research in improving mathematical creative thinking skills, such as research by Rahmawati et al. (2022). However, this research did not test how large or how strong the effect of the STEM approach is to improve students' creative thinking ability in learning mathematics. Hence, researchers need to conduct further research using meta-analysis, which aims to estimate and evaluate the effect of the STEM approach by analyzing and combining several primary studies that discuss relevant research topics. Meta-analysis is a popular way to combine evidence from multiple studies comparing multiple treatments or other interventions (White, 2015; Juandi & Tamur, 2021). Meta-analysis uses a quantitative approach and calculates the effect size to obtain accurate conclusions. In addition, researchers need to provide information about the characteristic study as a heterogeneity factor in implementing the STEM approach in learning mathematics, especially in improving students' mathematical creative thinking abilities.

METHODS

Meta-analysis is used to summarize quantitative data from a series of studies and make claims about the distribution of effect sizes in a series of studies that are eligible (Juandi & Tamur, 2020) or fit specified inclusion criteria. The use of meta-analysis in this study was to analyze and evaluate the effectiveness of the STEM approach in Mathematics learning on students' mathematical creative thinking ability. The selection of the random model took into account the diversity of the primary studies that analyzed education level, sample size, STEM integration, and the year of study, which was predicted to be the cause of the heterogeneity of mathematical creative thinking ability by first testing the heterogeneity of the data.

Generally, a meta-analysis uses the stages: definition of the research problem, data collection, coding process, application of statistical analysis, and presentation of results (Juandi & Tamur, 2020; Retnawati et al., 2014). In the other literature (Borenstein et al., 2009; Cooper et al., 2017), meta-analysis used these stages: defining the problem, inclusion criteria, literature search strategy, study selection, data extraction, statistical analysis, and interpretation and reporting. The stages are shown in Figure 1.

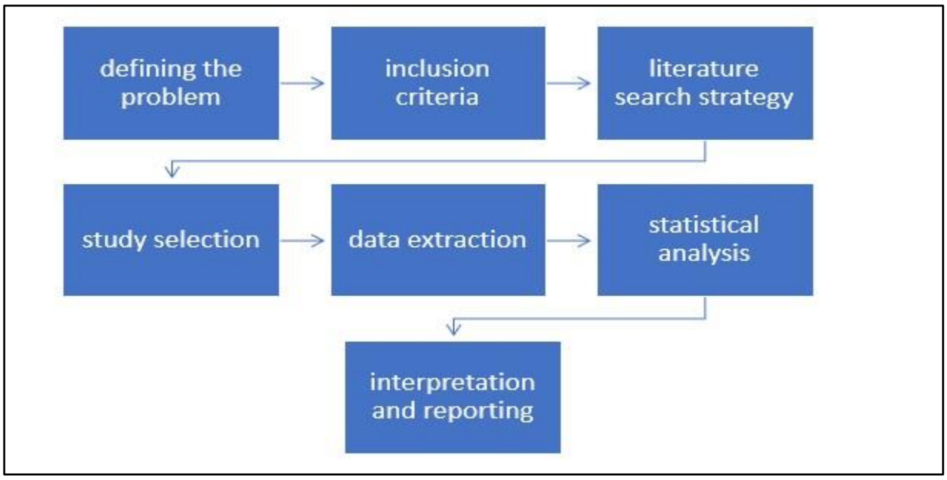

Figure 1. Flowchart of Meta-analysis Stages

To make the problem more focused and specific, the following inclusion criteria were used: treatment in the primary study was the STEM approach, the population in the primary study were students at the elementary, junior high, or senior high school levels, the outcome in the primary study was mathematical creative thinking ability, the comparator of the treatment in the primary study was non-STEM learning, primary studies used experimental or quasi-experimental research, primary studies in the form of articles in journals, proceedings, theses or dissertations published in 2017 to 2022, primary studies were quantitative studies and contain statistical data to get effect sizes which include sample size, standard deviation and mean, sample size and p-value or sample size and t-value for both treatment and comparison groups.

In finding primary studies according to inclusion criteria, researchers used several keywords, namely, "STEM Approach, Mathematical Creative Thinking," "STEM, Creative thinking skills in mathematics learning," "STEM Education, Creative thinking skills," “STEM, Creative thinking ability ."Primary studies are searched with search engines such as Google Scholar, ERIC (Education Resources Information Center), DOAJ (Directory of Open Access Journal), Research Gate, IOP publishing, AIP publishing, Science Direct, or through indexed URLs of national and international journals.

The study selection process in this study used the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) stages which refer to Liberati et al. (2009), namely the identification, screening, and eligibility stages so that produce primary studies that fit the inclusion criteria for further research.

At the identification stage, studies were selected based on the title, namely the effect of the STEM approach on the mathematical creative thinking ability. Through an electronic search engine, 84 articles were obtained according to the intended theme, which will be processed in the screening stage.

The screening stage was carried out by reading the abstracts of the studies obtained from the identification stage. In this stage, a selection was made on experimental/quasi-experimental studies, according to what was required in the meta-analysis. Seventeen studies fit the screening stage. According to the data requirements in the meta-analysis, only experimental/quasi-experimental studies with a control group will be processed in the next stage. Four studies among 17 did not have a control group, so these four were excluded. Therefore, only 13 studies will be selected at the eligibility stage.

At the eligibility stage, the 13 studies obtained were selected based on inclusion criteria. There was 1 study that did not provide statistical information, so it was excluded from the eligibility stage. Thus, the articles considered completely fit the inclusion criteria and were eligible to be included in the meta-analysis were 12 studies on the effect of STEM on the students' mathematical creative ability. There are three primary studies, which produced two effect sizes, namely the primary study from Suherman et al. (2021), the primary study from Yuniar et al. (2020), and the primary study from Noviyani (2022). So, the effect sizes on the students' mathematical creative thinking ability were fifteen.

Primary studies that met the inclusion criteria will be coded and extracted to obtain statistical information needed in the meta-analysis process for finding the effect size of the effect of STEM on the students' mathematical creative ability. In the coding process, two coders were involved. The extracted data were the author's name, statistical information such as sample size, mean, standard deviation, p-value, and t-value, education level, year of publication, and integration of STEM. The study selection stages are explained in more detail in the following flowchart, as shown in Figure 2.

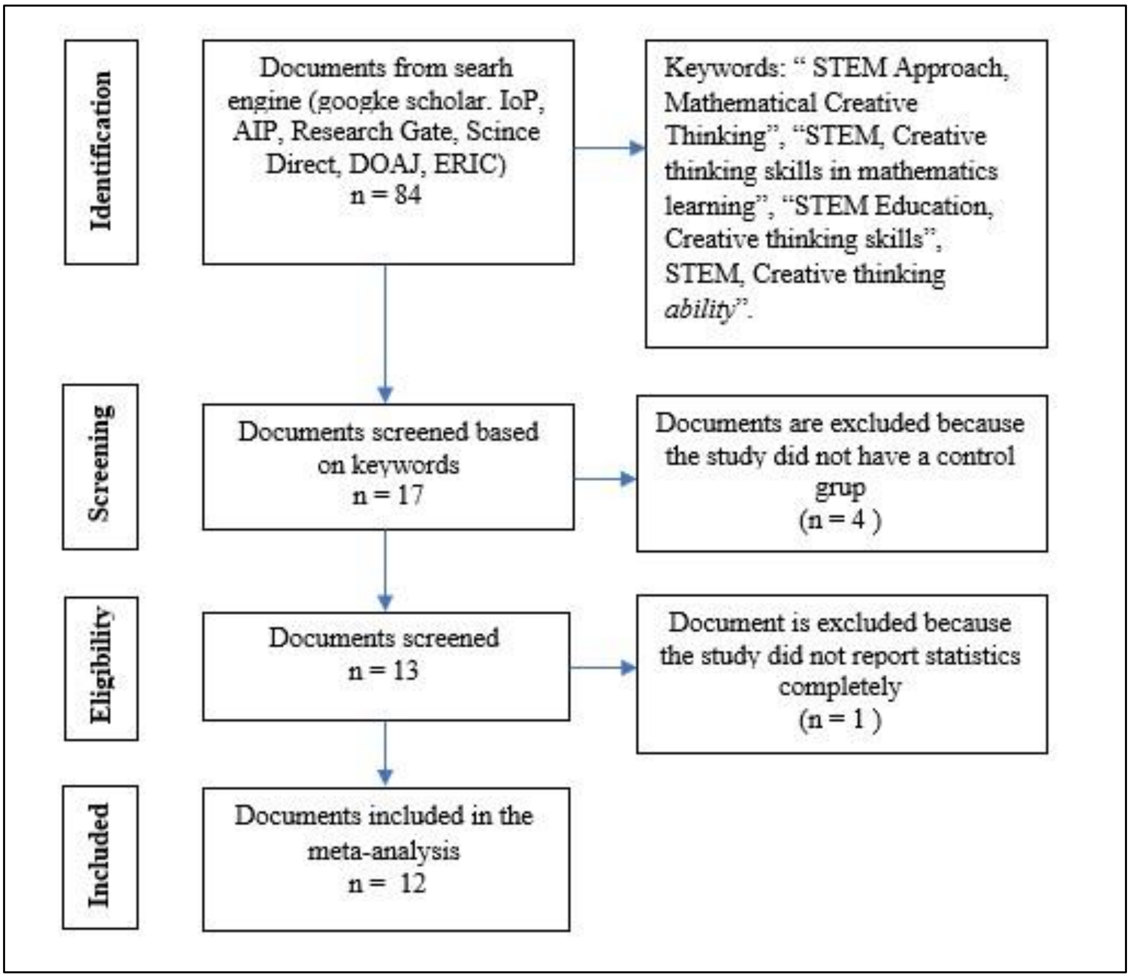

Figure 2. Flowchart for Study Selection Based on the PRISMA Stages

This meta-analysis calculated effect size using the Hedge G equation (Borenstein et al., 2009). Data processing uses Comprehensive Meta-Analysis 3.0 (CMA 3.0) software, a special meta-analysis software. In calculating the effect size, the statistical data needed is in the form of sample size, standard deviation and mean, sample size and p-value, or sample size and t-value. Data acquisition results regarding the effect size of each study or the combined effect size of the studies are then interpreted using the classification developed by Cohen (Juandi & Tamur, 2020).

Table 1. Interpretation of *Effect Size*

Range of Effect Size (ES)	Interpretation
$0,00 \leq ES < 0,20$	Ignored
$0,20 \leq ES < 0,50$	Small
$0,50 \leq ES < 0,80$	Moderate
$0,80 \leq ES < 1,30$	Large
$1,30 \leq ES$	Very Large

In meta-analysis research, publication bias must be investigated because sometimes statistically significant articles are published more often, and researchers rarely (6%) publish studies that are not significant (Cooper et al., 2017). This tendency can lead to a significant overrepresentation of studies, similar to actual studies (Borenstein et al., 2009). Therefore, a publication bias test was conducted to determine whether or not the study was resistant to publication bias. Several tests that can be performed to check publication bias are funnel plot, fill and trim test and N Rosenthal fail and save the test. The funnel plot aims to check whether the effect size distribution spreads symmetrically around the average effect size. If the effect size distribution is symmetrical, it can be said that each study has a small risk of publication bias (Retnawati et al., 2014). The trim and fill test results if there is no difference between the observed and adjusted values, meaning that the effect size distribution of the primary study is analyzed symmetrically.

After ensuring that the data were free from publication bias, the next step is to carry out a homogeneity test used as the basis for selecting the analytical model. Determination of test results based on p-value on Q-statistics (Borenstein et al., 2010; Retnawati et al., 2014). If the p-value is lower than 0.05, the distribution of effect sizes from the primary studies used in the meta-analysis process can be interpreted as heterogeneous. Thus, the analysis model chosen is the random effects model. Heterogenous effect size data indicated that analysis of study characteristics needed further investigation of the variables that might cause heterogeneity in effect size data (Borenstein et al., 2009; Hedges & Pigott, 2004). Meanwhile, if the p-value > 0.05, it can be interpreted that the distribution of the effect sizes of the primary studies used in the meta-analysis process is homogeneous. Thus, the analytical model chosen for the meta-analysis is the fixed effects model (Retnawati et al., 2014).

RESULTS AND DISCUSSION

The results of calculating the Effect Size of the implementation of the STEM approach on students' mathematical creative thinking ability are presented in Table 2:

Table 2. Effect Size of the STEM Approach to Mathematical Creative Thinking Ability

Code	Author	Effect Size	Confident Interval 95%		Standard Error	Interpretation
			Lower Limit	Upper Limit		
KF01	(Yunita et al., 2020)	0,689	0,174	1,203	0,262	Moderate
KF02	(Surmilasari et al., 2022)	0,697	0,202	1,193	0,253	Moderate
KF03	(Amiruddin& Juwairiyah, 2019)	1,508	0,84	2,176	0,341	Very Large
KF04	(Suherman et al., 2021)	1,348	0,811	1,885	0,274	Very Large
KF05	(Suherman et al., 2021)	0,82	0,307	1,332	0,262	Large
KF06	(Jawad et al., 2021)	0,642	-0,052	1,335	0,354	Moderate

KF07	(Yuniar et al., 2020)	1,443	0,862	2,025	0,297	Moderate
KF08	(Yuniar et al., 2020)	0,505	-0,02	1,030	0,268	Moderate
KF10	(Hobri et al., 2021)	3,328	2,576	4,081	0,384	Very Large
KF11	(Ismayani., 2017)	0,461	-0,012	0,934	0,242	Small
KF12	(Noviyani, 2022)	1,902	1,191	2,613	0,363	Very Large
KF13	(Noviyani, 2022)	0,231	-0,345	0,807	0,294	Small
KF14	(Amini, 2021)	-0,969	-1,774	-0,164	0,411	Ignored
KF15	(Roheni, 2021)	1,242	0,695	1,788	0,279	Very Large
KF16	(Anshori, 2022)	0,324	0,058	0,797	0,241	Small

It can be seen from Table 2 that the effect size of each study varies. The largest effect size is 3.328 in the KF10 study. Based on the interpretation of the effect size using the classification developed by Cohen, this is classified as a very large effect.

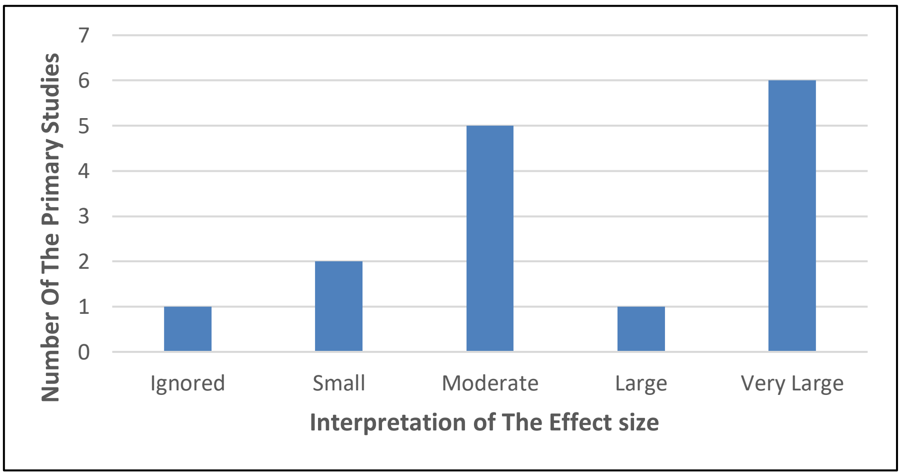

Figure 3. Distribution of Effect Size Data from Each Primary Study

Figure 3 shows that six studies had a very large effect size, one study had a large effect size, five studies had a moderate effect size, two studies had a small effect size, and one study had a negligible effect size. To check whether the effect size distribution spreads symmetrically around the average effect size, we can use a funnel plot.

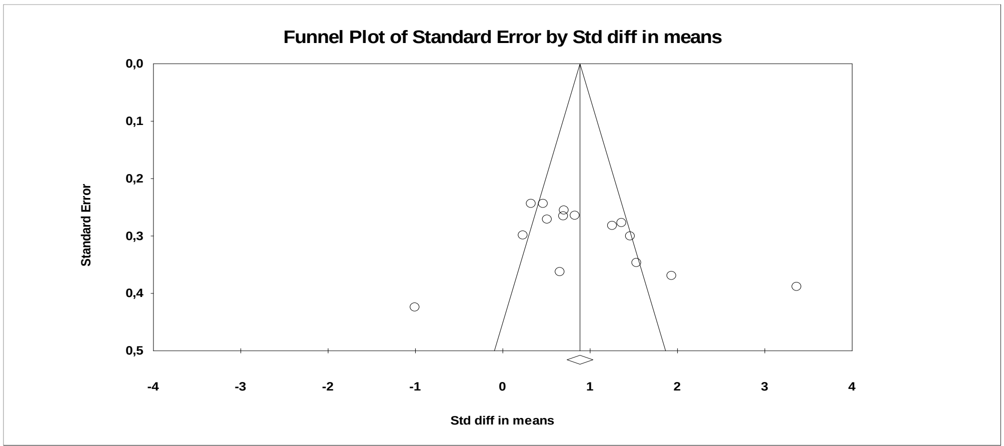

Figure 4. Distribution of Effect Size Data from Each Primary Study

Figure 4 shows that the distribution of effect sizes from each primary study looks almost symmetrical, so it can be said that each study has a small risk of publication bias. To ensure whether the distribution of the effect size data is symmetrical, a fill and trim test is used to assess the symmetry of the funnel plot. The results of the fill and trim tests using Comprehensive Meta-Analysis 3.0 (CMA 3.0) software are shown in Table 4.

Table 3. The result of the Fill and Trim Test

	Studies Trimmed	*Random Effects*		*Random Effects*		Q-value
		Point Estimate	**95% CI**	**Point Estimate**	**95% CI**	
Observed values	0	0,86986	[0,72337; 1,01634]	0,935	[0,54543; 1,32458	97,11528
Adjusted values		0,86986	[0,72337; 1,01634]	0,935	[0,54543; 1,32458	97,11528

The trim and fill test results in Table 3 show no difference between the observed and adjusted values, meaning that the effect size distribution of the primary study was symmetrical. Thus there is no need for additional studies or trimmed studies. It can be said that the funnel plot obtained in Figure 2 is quite symmetrical. It can be interpreted that the primary studies used in this meta-analysis have a small risk of publication bias.

After ensuring that the distribution of effect sizes was resistant to publication bias, the next step is to examine the heterogeneity of the effect sizes distribution using the Q-test, which is used to decide on the analytical model to be used. The Comprehensive Meta-Analysis 3.0 (CMA 3.0) software obtained the Q value.

Table 4. The Heterogeneity Test

Model	n	*Effect Size*	Q-value	df (Q)	p-value
Fixed	15	0,870	97,115	14	0,000
Random	15	0,935			

Based on the result of the heterogeneity test, the p-value is less than 0,05. The distribution of the effect sizes from the primary studies used in this meta-analysis can be interpreted as heterogeneous. Therefore the next step used a random effect model. The results of the estimated effect size of the combined studies analyzed are presented in Table 5.

Table 5. The Combined Effect Size of The Study based on the Random Effect Model

Model	n	Z value	p-value	Effect Size and 95% Confidence Interval				
				Point Estimate	Standard Error	Variance	Lower Limit	Upper Limit
Random	15	4,706	0,000	0,935	0,199	0,040	0,545	1,325

Table 5 shows the estimated effect size of the combined studies analyzed was 0.935. According to the interpretation of the effect size using the classification developed by Cohen, this effect size is in a large category. To determine whether the implementation of the STEM approach on students' creative thinking ability has a significant effect, we need to conduct the null hypothesis test. The result of the p-value was 0.000, which is less than 0.05. It indicated that the STEM approach significantly affects students' mathematical creative thinking ability. This result was in line with the results of research from (Amin et al., 2022), who conducted a meta-analysis for both science and mathematics subjects with the conclusion that STEM is effective on students' creative thinking ability. The combined effect size obtained in this study was 0,58 with a moderate effect category. The STEM stages in planning a solution provide students' creativity in generating many ideas to solve a given problem, developing various alternative solutions, and developing a problem-solving plan (Ulum et al., 2021).

The heterogeneity test that has been carried out with the acquisition of results in the form of effect sizes from primary studies with heterogeneous distribution makes it possible to carry out investigations of character studies that are suspected of moderating the influence of STEM on students' mathematical creative thinking abilities. The characteristics of the studies used in this study are the type of STEM integration with learning models, the publication year of the primary studies, educational stages, and sample size.

According to Baron & Kenny (Hedges & Pigott, 2004), study characteristics or moderator variables influence the direction and strength of the relationship between the independent or predictor variable and the dependent variable or criteria. The independent variable in this study was the STEM approach, while the students' mathematical creative thinking ability was the dependent variable. These study characteristics are predicted to be the factor that causes the heterogeneity of the effect of the implementation of STEM on students' creative thinking ability.

Table 6. Effect Sizes Based On Study Characteristics

Study Characteristics	**Category**	**N**	**Effect Size**	**95% CI**	**Heterogeneity Test**		**df**
					Q-value	**P-value**	
STEM integration	STEM	8	1,229	[0,011 ; 1,022]	23,117	0,000	1
	STEM-PjBL	7	0,511	[0,011 ; 0,304]			
Education level	Primary Schools	3	0,9	[0,555 ; 1,245]	9,949	0,007	2
	Junior High Schools	2	0,393	[0,058 ; 0,727]			
	Senior High Schools	10	1,007	[0,822 ; 1,192]			
Sample size	<=30	10	0,834	[0,646 ; 1,021]	0,366	0,545	1
	>30	5	0,926	[0,692 ; 1,160]			
Year of publication	2017 - 2018	1	0,461	[-0,012 ; 0,934]	5,716	0,057	2
	2019 - 2020	5	1,073	[0,823 ; 1,322]			
	2021 - 2022	9	0,815	[0,010 ; 0,619]			

Table 6 shows the effect sizes of the primary studies related to each study's characteristics. The effect sizes in STEM integration between the STEM and STEM-PjBL produced an effect size of 0,511. According to Cohen et al. (2007), this effect is moderate. Meanwhile, the class that applied STEM had an effect size of 1,229 which was included in the very large category. The Q-value obtained from the heterogeneity test was 23,117, and the p-value was 0.000, less than 0.05. This means there is a significant difference in effect size in terms of students who studied with the STEM approach and those who studied with the STEM-PjBL. Project-based STEM characteristics have similarities with PjBL as a learning model. In addition, integrated with PjBL, STEM can stimulate students to think creatively and collaborate in solving problems by producing projects (Anindayati & Wahyudi, 2020).

A meta-analytic study of the effectiveness of integrating the STEM approach with Project Based Learning (PjBL) conducted by Izzah & Mulyana (2021) was in line with the findings of this study. Despite reviewing the other dependent variables, the conclusions in that meta-analysis did not obtain conflicting decisions that PjBL integrated STEM is practical to apply, both to improve creative thinking abilities and learning outcomes.

Based on the educational level, the Q value obtained from the heterogeneity test was 9,949, and the p-value was 0,007, less than 0,05. This means there are differences in the effect size of the STEM approach on students' mathematical creative thinking ability in terms of educational level between students who study at the elementary, middle, or high school levels. Research by Tamur et al. (2021), who conducted a meta-analysis on various subjects such as mathematics and science at the elementary, junior high, high school, and tertiary education levels, concluded that educational level is one of the character studies that are causing the heterogeneity of the effect size of the STEM approach to the achievement.

In this study, the sample size of the STEM class was categorized into two groups: a sample size of less than or equal to 30 and a sample size of more than 30. The Q value obtained from the heterogeneity test was 0,366, and the p-value was 0,545, less than 0,05. This means that there is no different significant effect size in the STEM approach on students' creative thinking ability in terms of sample size. This means that the sample size of the STEM class is independent of students' mathematical creative thinking abilities. The effect size produced by courses with a sample size of more than 30 is 0,870, and the effect size produced by classes with a sample size less than or equal to 30 is 0,834. The two effect sizes are equally large. So, with these results, it can be seen that the effect size in the sample size category is not a heterogeneity factor in applying the STEM approach to students' creative thinking ability. This result aligns with a meta-analysis of PjBL on creative thinking skills by Yunita et al. (2021), which concluded that sample size did not affect the heterogeneity of creative thinking abilities. So, it can be interpreted that samples of any size can implement the STEM approach with good results, and students who study with STEM in both sample size categories increase their mathematical creative thinking abilities not significantly different.

The year of publication was divided into three categories, namely the year 2017-2018, the year 2019-2020, and the year 2021-2022. The Q value from the heterogeneity test was 5,716, and the p-value was 0,057, less than 0.05. Thus, it can be concluded that the effect of STEM on students' mathematical creative thinking skills between study year of publication groups was similar. This means there is no difference in the effect size in the year of publication. Thus there is no difference in students' mathematical creative thinking abilities in terms of the year of research publication. During the Covid 19 pandemic, the learning process depended on technology. A sudden change from a face-to-face learning system to online learning requires teachers to be more creative in delivering subjects. Likewise, students must be creative in finding learning resources from various learning sources. The result is that the year of publication (often the same as the year the research was conducted) is not the cause of heterogeneity in students' mathematical creative thinking abilities. It means that STEM can be done anytime, even during a pandemic. This indicates that STEM can be carried out both online and offline, with the finding of the fact that in the online period, STEM-based learning and research can still be carried out (Handayani, 2020).

The limitation of this study due to this study only examined four study characteristics. The author hopes that more researchers will conduct research related to the implementation of STEM on students' mathematical creative thinking ability with more study characteristics that can be examined.

CONCLUSIONS

A meta-analysis of the 12 primary studies in this study gives information that the STEM approach is effective on students' mathematical creative thinking ability with an effect size of 0.935 in the category of large effect. The teachers are suggested to implement STEM in their learning processes in both online and offline learning. STEM can also be implemented in both small and big classes.

For further meta-analysis study need to use more primary studies. The next researcher can also investigate and analyze other skills, such as critical thinking, problem-solving, and other skills. Moreover, study characteristics such as research areas and treatment duration must be investigated further.

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AUTHOR CONTRIBUTIONS STATEMENT

LR was the main researcher, instrument designer, and main drafter. DJ was a supervisor who provided initial research ideas, reviewed research instruments and guided the research process. EN was a supervisor who provided suggestions regarding the initial research idea, reviewed research instruments and guided the research.

REFERENCES

Amin, M., Ibrahim, M., & Alkusaeri. (2022). Meta analisis: Keefektifan STEM terhadap kemampuan berpikir kreatif siswa. *Journal of Authentic Research on Mathematics Education (JARME)*, *4*(2), 248–262.

Amini, N. K. (2021). *Penerapan model pembelajaran project-based learning (PjBL) berbasis stem untuk meningkatkan kemampuan berpikir kreatif matematis peserta didik (Penelitian kuasi eksperimen di kelas VIII SMP Negeri 1 Cikijing)*. Universitas Islam Negeri Sunan Gunung Djati.

Amiruddin, B., & Juwairiyah, A. (2019). STEM education in integrative thematic learning to improve students' creative thinking abilities in elementary school. *STEMEIF (Science, Technology, Engineering and Mathematics Learning International Forum) Purwokerto April 25th 2019*, 210–218.

Anindayati, A. T., & Wahyudi, W. (2020). Kajian pendekatan pembelajaran STEM dengan model pjbl dalam mengasah kemampuan berpikir kreatif matematis siswa. *Eksakta: Jurnal Penelitian dan Pembelajaran MIPA*, *5*(2), 217–225.

Anshori, H. (2022). *Peningkatan kemampuan berpikir kreatif dan self-efficacy matematis siswa sma melalui pembelajaran daring model project-based learning dengan pendekatan STEAM*. Universitas Pendidikan Indonesia.

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). Introduction to meta-analysis. In *International Statistical Review* (Vol. 77, Issue 3). John Wiley & Sons, Ltd Registered.

Borenstein, M., Hedges, L. V, Higgins, J. P. T., & Rothstein, H. R. (2010). *A basic introduction to fixed-effect and random-effects models for meta-analysis*. *August*.

Cohen, L., Manion, L., & Morrison, K. (2007). Research methods in education. In *Research Methods in Education* (Sixth).

Cooper, H. M., Valentine, J. C., & Hedges, L. V. (2017). Handbook of research synthesis and meta-analysis 2nd edition. In *The Lancet*, *389*(10082).

Handayani, F. (2020). Membangun keterampilan berpikir kritis siswa melalui literasi digital berbasis STEM pada masa pandemik covid 19. *Cendekiawan*, *2*(2), 69–72.

Hedges, L. V., & Pigott, T. D. (2004). The power of statistical tests for moderators in meta-analysis. *Psychological Methods*, *9*(4), 426–445.

Hidayat, M. A. H., & Rahmi, S. (2022). Teknik belajar matematika yang menyenangkan bagi siswa Sekolah Menengah Atas (SMA). *Jurnal Pema Tarbiyah*, *1*(1), 44–53.

Hobri, Adeliyanti, S., Fatekurrahman, M., Wijaya, H. T., Oktavianingtyas, E., Putri, I. W. S., & Ridlo, Z. R. (2021). E-Comic mathematics based on STEAM-CC and its effect on students creative thinking ability. *Journal of Physics: Conference Series*, *1839*(1).

Izzah, N., & Mulyana, V. (2021). Meta analisis pengaruh integrasi pendidikan STEM dalam model project based learning terhadap hasil belajar siswa. *Jurnal Penelitian Pembelajaran Fisika*, *7*(1), 65–76.

Jawad, L. F., Majeed, B. H., & Alrikabi, H. T. S. (2021). The impact of teaching by using STEM approach in the development of creative thinking and mathematical achievement among the students of the fourth scientific class. *International Journal of Interactive Mobile Technologies*, *15*(July), 172–188.

Juandi, D., & Tamur, M. (2020). *Pengantar analisis meta*. UPI Press.

Juandi, D., & Tamur, M. (2021). The impact of problem-based learning toward enhancing mathematical thinking: A meta-analysis study. *Journal of Engineering Science and Technology*, *16*(4), 3548-3561.

Kholil, M., & Safianti, O. (2019). Efektivitas pembelajaran penemuan terbimbing terhadap hasil belajar matematika siswa materi barisan dan deret. *Laplace: Jurnal Pendidikan Matematika*, *2*(2), 89–98.

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ (Clinical Research Ed.)*, *339*.

Meika, I., & Sujana, A. (2017). Kemampuan berpikir kreatif dan pemecahan masalah matematis siswa SMA. *Jurnal Penelitian Dan Pembelajaran Matematika*, *10*(2), 8–13.

Noviyani, A. (2022). Pengaruh penerapan project based learning terintegrasi STEM (PjBL-STEM) dan problem based learning (PBL) terhadap kemampuan berpikir kreatif matematis ditinjau dari motivasi belajar siswa. *Braz Dent J.*, *33*(1), 1–12.

Rahmawati, L., Juandi, D., & Nurlaelah, E. (2022). Implementasi STEM dalam meningkatkan kemampuan berpikir kritis dan kreatif matematis. *Aksioma: Jurnal Matematika dan Pendidikan Matematika*, *11*(3), 2002–2014.

Retnawati, H., Apino, E., & Kartianom. (2014). Pengantar analisis meta. In E. Apino (Ed.), *Materi Workshop PRES BI, Jakarta 2-3 September 2014* (pertama, Issue August 2019). Parama Publishing.

Roheni, S. (2021). *Pengaruh model STEM (Science, Technology, Engineering, and Mathematic) menggunakan bahan ajar desain didaktis terhadap kemampuan berfikir kritis dan berfikir kreatif*. Universitas Islam Negeri Lampung.

Sakinah, K., & Widodo, W. (2019). Efectiveness of steam-based teaching materials to improve students' creative thinking skills. *Pensa E-Jurnal: Pendidikan Sains*, *7*(3), 338–342.

Siregar, N. R. (2017). Persepsi siswa pada pelajaran matematika: Studi pendahuluan pada siswa yang menyenangi game. *Prosiding Temu Ilmiah X Ikatan Psikologi Perkembangan Indonesia*, 224–232.

Suherman, Vidákovich, T., & Komarudin. (2021). STEM-E: Fostering mathematical creative thinking ability in the 21st Century. *Journal of Physics: Conference Series*, *1882*(1).

Surmilasari, N., Marini, & Usman, H. (2022). Creative thinking with stem-based project-based learning model in elementary mathematics learning. *Jurnal Pendidikan Dasar Nusantara*, *7*(2), 434–444.

Tamur, M., Fedi, S., Sennen, E., Marzuki, Nurjaman, A., & Ndiung, S. (2021). A meta-analysis of the last decade STEM implementation: What to learn and where to go. *Journal of Physics: Conference Series*, *1882*(1).

Ulum, M. B., Putra, P. D. A., & Nuraini, L. (2021). Identifikasi penggunaan EDP (Engineering Design Process) dalam berpikir engineer siswa SMA melalui Lembar Kerja Siswa (LKS). *Jurnal Riset Dan Kajian Pendidikan Fisika*, *8*(2), 53.

White, I. R. (2015). Network meta-analysis. *The Stata Journal*, *4*, 951–985.

Yuniar, D., Hobri, Prihandoko, A., Aini, K., & Faozi, A. K. (2020). The analyze of students' creative thinking skills on Lesson Study for Learning Community (LSLC) based on Science, Technology, Engineering, and Mathematics (STEM) approach The analyze of students' creative thinking skills on Lesson Study for Learn. *Journal of Physics: Conference Series*.

Yunita, Y., Juandi, D., Hasanah, A., & Tamur, M. (2021). Studi meta-analisis: Efektivitas model project-based learning terhadap kemampuan berpikir kreatif matematis siswa. *Aksioma: Jurnal Program Studi Pendidikan Matematika*, *10*(3), 1382.

Yunita, Y., Juandi, D., Tamur, M., Adem, A. M. G., & Pereira, J. (2020). A meta-analysis of the effects of problem-based learning on students' creative thinking in mathematics. *Beta: Jurnal Tadris Matematika*, *13*(2), 104–116.