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How is The Impact of Applying Contextual Approach in Mathematics Learning?

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ABSTRACT. This meta-analysis examines the effectiveness of multi-contextual approaches in mathematics learning and explores moderator variables that influence their impact. A total of 27 effect sizes from 14 empirical studies (2015–2023) involving 2,501 students were analyzed using a random effects model via R Studio. Studies were sourced from major academic databases, including ERIC, Scopus, Web of Science, and PubMed. The analysis yielded an overall effect size of 0.65 ($p < 0.0001$), indicating a substantial impact on students' mathematical abilities. Moderator analysis revealed that educational level, instructional model combinations, and geographic region significantly influenced effectiveness, while sample size did not. Notably, integrating mathematics with technology and Realistic Mathematics Education (RME) produced the highest effect sizes. These findings support multi-contextual strategies to enhance mathematics learning outcomes and offer valuable insights for educators, curriculum developers, and researchers. The study also highlights the need for future research across diverse educational settings to refine and contextualize effective practices. The study encourages educators to adopt culturally and technologically relevant teaching practices. It also calls for policy support in scaling contextual learning models and investing in teacher training across educational settings.

Keywords: *Meta-analysis; Multi-contextual approach; Mathematics learning; Effect size; Moderator variables*

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INTRODUCTION

In the future, students will face job requirements that necessitate the ability to comprehend and apply interdisciplinary knowledge, particularly within the realm of mathematics education. This implies that they must be capable of integrating skills and knowledge from diverse fields, extending beyond mere computational techniques, to achieve success in their careers (Schwabe et al., 2017). The traditional approach to education does not sufficiently develop the necessary mathematical skills and abilities, necessitating the design of a new method of teaching and learning (Crnković et al., 2022); (Benavides-Varela et al., 2020). Inequality in education, especially in terms of mathematics anxiety, is a critical issue that affects students' developmental trajectories (Wang et al., 2020). Mathematics anxiety is not just about fear or apprehension towards mathematics itself, but also about how cognitive, personality, and environmental factors interact and affect students' learning experiences in school. Addressing this issue is crucial and requires ongoing intervention, as indicated in international policy documents such as the United Nations 2019 Climate Action Summit Report (Healy, 2014); (Nguyen Thi Nga et al., 2023); (Dulama & Magdas, 2014); (Sass et al., 2023). Current efforts should focus on shifting the presentation of mathematics lessons from traditional methods to a more student-centered approach (Columbano, 2019); (Gervasoni & Peter-Koop, 2020); (Faragher et al., 2016).

A conducive environment is essential for realizing an effective experimental teaching model. Luitel (Luitel, 2018), suggests undertaking efforts to create inclusive and transformative approaches in mathematics teaching. A comfortable and predictable environment can reduce stress and anxiety, which are barriers to learning (Gervasoni & Peter-Koop, 2020); (Das, 2021); (Faragher et al., 2016); (Luitel, 2018). This requires us to thoughtfully consider how mathematics curriculum can be designed not only to transfer knowledge but also to encourage a broader understanding among all students (Luitel, 2018); (Kania & Juandi, 2023). In Slovenia, the learning process tends to place less emphasis on active student engagement and has yet to achieve the integration of interdisciplinary involvement (Cotič et al., 2015). In Romania, a new initiative in curriculum design has been realized through the development of an innovative syllabus, "Mathematics and Environmental Exploration." This model approach has received official approval from the Romanian Minister of National Education (Dulama & Magdas, 2014). The emphasis is placed more on mathematics and environmental education, along with outlining procedures for organizing and concretely implementing interdisciplinary integration (Cotič et al., 2015); (Supriadi et al., 2022); (Greenstein & Baglieri, 2018).

Indonesia has taken an innovative step in education by adopting the Merdeka Curriculum. This curriculum incorporates the principle of differentiated learning, designed to meet the unique needs of each student (Adams & Pierce, 2006); (Gusteti & Neviyarni, 2022); (Safarati & Zuhra, 2022). This relates to the challenge of ensuring that every student has equal access to learning, regardless of their background, ability, or special needs. Inclusive Mathematics emerges as a response to this challenge, emphasizing an inclusive and accessible mathematics education for all (Moreira & Manrique, 2014); (Padilla & Tan, 2019); (Tan, 2017). Teachers also need to be capable of providing solutions to enhance the quality of learning by utilizing approaches that are relevant to mathematics education (Vodičková et al., 2023); (Lisenbee & Tan, 2010).

Mathematics is not only a vital foundation in education, from elementary school until college, but also plays a crucial role in everyday life (Illene et al., 2023). Its ability to develop reasoning and critical thinking is key to solving various problems (Lisenbee & Tan, 2010); (Padilla & Tan, 2019); (Priyambodo et al., 2023). Every mathematical concept taught in school can be viewed as part of a larger network, reflecting the thoughts, values, and practices of various cultural groups. (Luitel, 2018); (Zakiah et al., 2019); (Sunzuma et al., 2021). By allowing students to participate in decision-making processes through deliberative discussions on controversial real-world issues, they will develop sustainability competencies (Sass et al., 2023); (Healy, 2014); (Elmedina Nikoçeviq-Kurti, 2022). Supporting this view, the research findings of Mefa Indriati et al. (Indriati et al., 2022) demonstrate that integrating indigenous engagement into the curriculum. Teaches mathematics not just as an academic subject, but also as a vital tool for understanding the world and its diverse cultures. This aligns with the findings of Hendriyanto et al. (Hendriyanto et al., 2023), reinforcing the understanding that mathematics is an intrinsic part of human life and deeply relevant to the way we live, think, and solve problems in our daily lives. This supports the realization of inclusive education.

Contextual learning offers an engaging experience that encourages critical thinking, problem-solving, and teamwork, making it a unique opportunity to address the challenges of mathematics learning, often perceived as difficult, boring, and intimidating (Sidekerskienė & Damaševičius, 2023); (Tambak et al., 2023). Previously, Trujillo et al. (2016), Prahmana et al. (2020), and Muhtarom et al. (2019) conducted experimental studies by combining approaches to contextual mathematics learning (Trujillo et al., 2016); (Prahmana et al., 2020); (Muhtarom et al., 2019). Learning can be verified and measured during implementation, and the feedback provided can support the enhancement of students' mathematical abilities (Sitthikrai et al., 2023). The findings of these studies indicate that introducing children to learning through real-world approaches has an impact on their mathematical achievements. However, these studies do not sufficiently explain the impact of the success of multi-contextual mathematics learning approaches.

This research has reviewed and categorized approaches in mathematics education research by analyzing 68 articles from 8 leading international journals over the past decade. The results show 7 main categories, including the extent to which articles on multi-contextual approaches in mathematics are published, the main topics studied, students' abilities, the use of terms contextual and multi-contextual approaches, and the methodology used in research, as described by Prahmana. Additional research by Muslimin, Putri, Zulkardi, and Aisyah also examines the use of the RME approach in Indonesia, including the history of EMR introduction, government measures, and the development of related educational programs. Both studies did not use quantitative methods or statistical analysis, leading Prahmana and his team to recommend further research with quantitative methods for more comprehensive results.

This study has reviewed and categorized approaches in mathematics education research by analyzing 86 articles from 8 leading international journals over the past decade. The results revealed 7 main categories, including the extent to which articles on multi-contextual approaches in mathematics were published, the main topics investigated, student abilities, the use of the terms contextual and multi-contextual approaches, and the methodology used in the research, as described by Prahmana et al. (Prahmana et al., 2020). Additional research by Muslimin, Putri, Zulkardi, and Aisyah (Muslimin et al., 2020) also examined the use of the RME approach in Indonesia, including the history of the introduction of RME, government measures, and the development of related educational programs. These two studies did not use quantitative methods or statistical analysis, so Prahmana and the team recommend further research with quantitative methods for more thorough results.

This study expands on previous research by evaluating the impact of successful approaches to overall mathematics learning on students' math skills. Investigations into the causes of effect size variations between individual studies were conducted by analyzing the relationships between identified moderating variables, i.e., differences in sample size, differences in education levels, combinations of learning, and countries of implementation of multi-contextual approaches. The results of this study provide reliable information to educators about the successful implementation of multi-contextual mathematics learning approaches in the future. The following ideas and questions are the ones that drove this research. Does the implementation of a multi-contextual mathematics learning approach produce a larger effect size than conventional mathematical approaches? Do differences in sample size, education level, learning combination, and geographic area of implementation of a multi-contextual math learning approach provide a measure of the overall effect of the study?

METHOD

The study used meta-analyses to scan through a large number of journals at national and international levels. This study deals with the impact of various multi-contextual applications in learning approaches such as RME, ethnomathematics, PBL, and environment-based approaches in the mathematics domain. In general, Borenstein et al. summarized the steps of the meta-analysis, starting with the establishment of inclusion criteria for research under consideration (Borenstein et al., 2009). Second, empirical data collection methods and coding of research variables are defined. Third, explain statistical techniques. This study also follows this method

RESULT AND DISCUSSION

Result

Inclusion Criteria

All articles included in basic searching then they are screened and evaluated for consideration and then included in a meta-analysis based on the following criteria: (a) Publication year range 2015-2023; (b) research areas in different countries; (c) in primary, and secondary and higher education environments; (d) using various approaches such as RME, ethnomathematics, contextual, PBL, PjBL, constructivist, inquiry, mathematical inclusion; (d) experimental research using control classes; (e) contain sufficient statistical data to determine the magnitude of the impact, and (f) a full article is available. Searching results using an electronic database found 2.115 studies. Furthermore, these studies are screened based on inclusion criteria set by the researcher.

After screening 2.115 preliminary studies, 14 primary studies were used as meta-analysis data sources. Of these 14 studies, 7 of them assessed more than one effect of applying various contextual approaches to mathematics learning, namely the research of Anderson et al., Giovanni et al., Gladys et al., Nastja et al., Sabina Ndiung et al., Kai-Hsiang et al., and Kendale et al., so that there were 27 studies analyzed in this meta-analysis study.

Data Collection

The main studies were obtained using relevant terms from an online database (see Figure 1). Data filtering using Preferred Reporting Items for Systematic Review and Meta-Analysis rules (PRISMA; see Figure 1). The PRISMA protocol is a systematic review method that supports high-quality meta-analyses (Pigott & Polanin, 2020).

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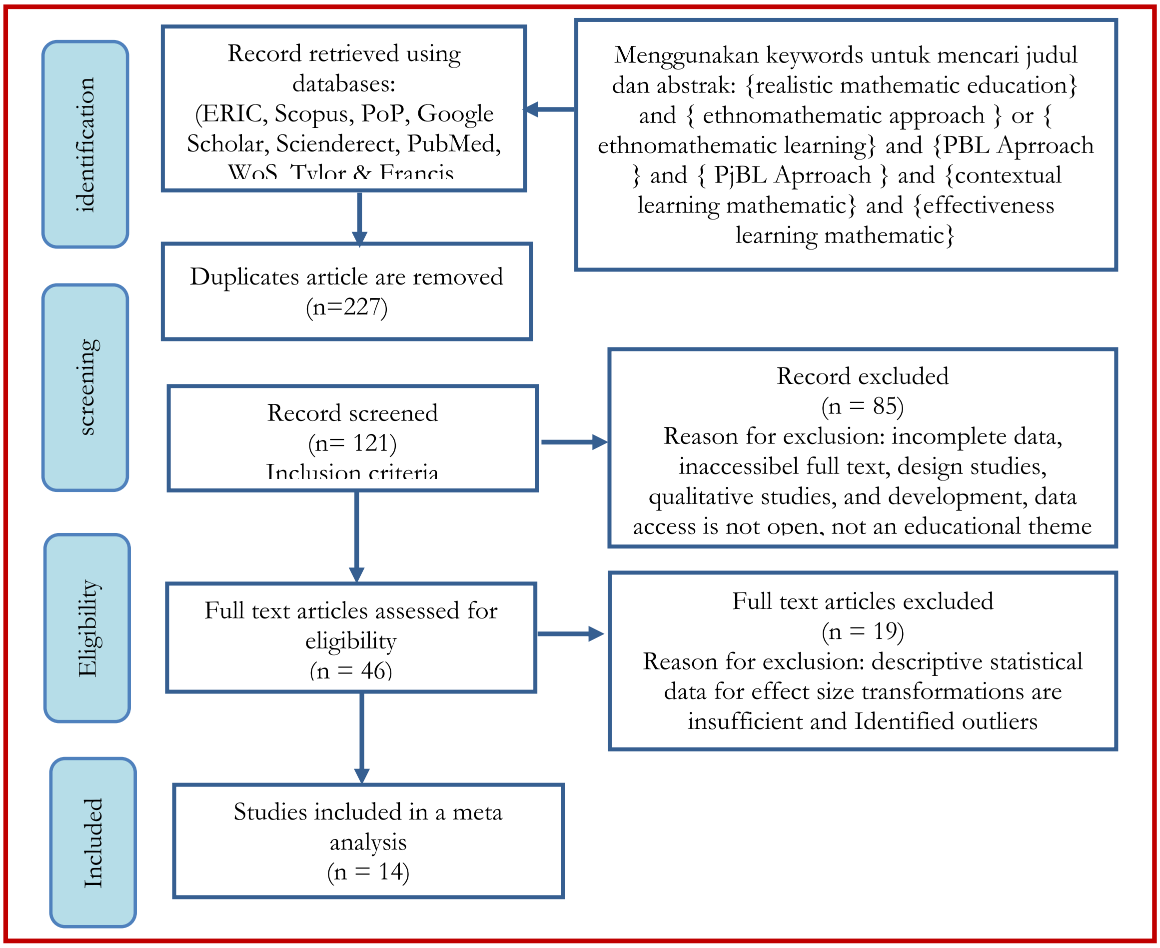

Figure 1. A flowchart illustrating how PRISMA is used to conduct an investigative meta-analysis of success profiles in multi-contextual mathematics learning approaches.

Process of Coding and Reliability Test

The studies included in further analysis are coded according to the objectives of the study. Research instruments are coding techniques used to convert certain research results into numerical data. This information includes sample size, differences in education levels, learning combinations, and countries that implement a multi-contextual approach to mathematics learning.

Every year article publication related to the success of multi-contextual mathematics learning approaches has succeeded in improving mathematics skills, especially in the last decade. The moderator variable of publication year was chosen to analyze differences in research results over time. Therefore, the publication source of this research only uses articles that have been published in international journals in the last ten years 2015-2023.

In Indonesia, there are four levels of education (1) early childhood education programs; (2) basic education programs (SD); (3) secondary education programs (junior high, high school, and vocational school); and (4) higher education programs (Universities). However, this research is limited only to the school environment (elementary, middle, and high school). Analysis of 14 major studies showed that they were spread across elementary, middle, and high school levels. Sample size variables were selected to analyze differences between study results based on different sample sizes. The researchers assigned the sample sizes into two categories: sample sizes < 50 and > 51. The number 50 was chosen because it took the middle value on the sample used in 14 studies.

Moderator variables

Meta-analysts always identify moderation variables, that is, characteristics of individual research related to research results (Hall & Rosenthal, 1991). The moderator in this study is a variable that affects the application of various contextual approaches in improving mathematical skills. The variable coding results provide five identifiable moderators: sample size, education stage, combination of learning approaches, and geographic region. Details of the four moderators are listed in Table 1.

Tabel 1. Information of Moderator Variables

Category	Group	N
Sample Size	50 or less	6
	51 or over	21
Educational stage	Primary school (PS)	8
	Junior High School (JHS)	12
	Senior high school (SHS)	7
Combination of learning	Math learning +RME	8
	Math learning +Ethnomathematics	5
	Math learning + technology	8
	Math learning + environmental	2
	Math learning + PBL	4
Geographical region	Indonesia	11
	Liverpool	2
	Vietnam	2
	Zimbabwe	2
	Slovenia	2
	Taiwan	2
	Caribbean	6

Statistic Analysis

The data analyzed in the meta-analysis is an effect size (Glass, 2015). The effect size in this study is an index that measures the effect of mathematics learning in multi-contextual-based. Each analysis is calculated using R studio software. Calculating the effect size of each study found aims to be able to combine and compare the impact produced statistically for each study found (Retnawati et al., 2018). The effect size is calculated using the Hedges Equation g (Borenstein et al., 2009), while the interpretation is based on Cohen's (1988) classification. The size of the summary effect is obtained by calculating the size effect for the difference between two independent groups can use Cohen's classification: $0 < d < 0.2$ (weak); $0.2 < d \leq 0.5$ (Medium); $0.5 < d \leq 0.8$ (strong); $d > 0.8$ (very strong). The amount of summary effect is obtained from the calculation of the effect size of each study to know the success profile of the multi-contextual mathematics learning approach.

The heterogeneity test was performed by examining the Q statistics and p values to see the size of t h e variance effect between studies analyzed using R studio. The data information obtained comes from a sample (not a population) giving rise to the assumption that the actual effect size varies from study to study, not only because of measurement errors, but also because of differences in study design, population, intervention, and outcome measurement (Retnawati et al., 2018). Therefore, the Random Effect model estimation approach is more suitable to be used in determining Q values to test heterogeneity. If the Q value is significant, this indicates a substantial heterogeneity between studies (Pigott & Polanin, 2020).

Due to the relatively large number of studies included in the analysis, this study used 5% ($p<0.05$) as the significance level. Therefore, if the p-value <0.05, it states that all studies are different (heterogeneous) and therefore homogeneous (H0) is not accepted and this means that it is not possible to calculate the parameters of the same population. (Borenstein et al., 2009);

(Suparman, Juandi, D., & Tamur, 2021). In other words, the effect sizes between studies or categories differ (Turgut, S., & Turgut, 2018). The heterogeneity between study groups suggests that differences in moderators affect the size of the study effect (Juandi et al., 2022a).

In the publication bias analysis, this study used Hedges' g equation. This equation is a variation of Cohen's equation that is adjusted to provide a more unbiased estimate, especially in smaller samples. Hedges' g equation takes into account possible biases in the estimation of effect sizes and is usually considered to give more accurate results (Harwell, 2020). Publication bias checks are conducted to prevent misrepresentation of findings. To what extent any 46 studies included in the review had sample bias, will appear in a summary of the overall size of the reported effect (Borenstein et al., 2009). As a result of this publishing bias, academics are less likely to publish insignificant ones compared to statistically significant findings (6 %) (Cooper, 2017). Researchers are concerned that the results of this study may overestimate the magnitude of the actual effect (Arik, S., & Yilmaz, 2020); (Ferguson, C. J., & Heene, 2012); (Park, S., & Hong, 2016). In anticipation of this, Rosenthal's funnel plots and FSN statistics were examined to assess the possible amount of bias (Borenstein et al., 2009); (Juandi et al., 2022). This study is said to be bias-resistant if it shows a symmetrical distribution along a vertical line (Borenstein et al., 2009). If the effect size is not symmetrically distributed, then the Fail-safe N (FSN) statistic is used. If $FSN/(5k+10)>1$, where k is the number of studies included in the meta-analysis, the study is immune to publishing bias (Mullen, B., Muellerleile, P., & Bryant, 2001).

Data screening procedures were followed to ensure the studies used in this meta-analysis met the inclusion criteria. After this screening, 14 individual studies, providing 27 independent samples, were analyzed. Table 2 presents the study name, year of publication, N (sample size), stage of education, and ES (effect size).

Table 2. Summary of individual studies analyzed

No	Author	Year	N	Educational stage	ES
1	Nguyen et al.	2023	78	Senior high school	0.5303
2	Anderson et al. study 3	2021	105	Junior high school	1.2879
3	Anderson et al. study 4	2021	82	Junior high school	0.4278
4	Anderson et al. study 5	2021	71	Junior high school	0.8138
5	Anderson et al. study 6	2021	117	Junior high school	0.735
6	Duong Huu et al.	2021	87	Junior high school	0.7342
7	Uba Umbara et al.	2019	65	Junior high school	0.8211
8	Giovanni et al. study 4	2017	180	Primary school	0.3048
9	Giovanni et al. study 5	2017	113	Primary school	0.0648
10	Andi et al.	2020	60	Junior high school	0.5606
11	Gladys et al. study 1	2021	90	Junior high school	0.8146
12	Gladys et al. study 2	2021	90	Junior high school	0.7854
13	Nastja et al. study 1	2015	331	Primary school	0.3938
14	Nastja et al. study 3	2015	331	Primary school	0.2958
15	Suherman et al.	2020	60	Junior high school	0.002
16	Novitasari et al.	2022	60	Junior high school	0.0027
17	Rahmi Hidayati et al.	2019	51	Junior high school	1.3333
18	Sabina Ndiung et al. study 1	2021	101	Primary school	0.8594
19	Sabina Ndiung et al. study 2	2021	101	Primary school	0.8162
20	Kai-Hsiang et al. study 1	2022	59	Primary school	1.3895
21	Kai-Hsiang et al. study 2	2022	59	Primary school	0.528
22	Kendale et al. study 1	2021	35	Senior high school	0.1037
23	Kendale et al. study 2	2021	35	Senior high school	0.9425

24	Kendale et al. study 3	2021	35	Senior high school	1.2253
25	Kendale et al. study 4	2021	35	Senior high school	0.8004
26	Kendale et al. study 5	2021	35	Senior high school	0.7287
27	Kendale et al. study 6	2020	35	Senior high school	1.1492

Note: To represent studies that produce more than one effect size, we use 1, 2, 3. The effect size refers to Hedges' equation, g.

Table 2 shows individual studies conducted between 2015 and 2023. In education, junior high school participants occupy the largest proportion (44.4%), 29.6% are elementary school level and 25.9% are high school level. Furthermore, based on the main study countries conducted, Indonesia contributed the most (40.7%), and the rest were spread in Liverpool (UK), Vietnam, Zimbabwe, Slovenia, Taiwan, Caribbean (America). Individual studies with more than 51 students were 77.8% and less than 50 were 22.2%. Finally, by considering the combination of mathematics learning followed by the RME approach (29.6%), followed by the ethnomathematics approach (18.5%), followed by the technology approach (29.6%), followed by an environment-based approach (7.4%), and a PBL approach (14.8%).

First, this study examines the overall impact of learning mathematics with a multi-contextual approach in improving students' abilities. Figure 2 presents the florest plot study which illustrates effect sizes, confidence intervals, and standard errors from 27 studies. It appears that there are broad levels of confidence and varying levels of response, suggesting there is a clear heterogeneity in the study. Figure 2 also presents an estimation analysis of random effect models from 27 studies, and graphically illustrates the size of the effect (square point). The confidence interval estimation is a horizontal line that extends from both sides.

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27 effect measures in the meta-analysis ranged from 0.002 to 1.3895 with 100% of studies having positive effect sizes. This illustrates that all studies reported learning mathematics that applied a variety of contextual approaches better than a control group. Learning with a multi-contextual approach provides direct and relevant experience in students' daily lives. Procedurally, students' mathematical thinking skills will fail if students try to understand problems, connect and present related mathematical concepts, and generalize. The results of the analysis showed that 14.8% of studies had a weak effect size, 14.8% had a medium effect size, 55.6% had a strong effect size, and 14.8% had a very strong effect size.

The number of samples in the meta-analysis ranged from 35 to 331 students (a combination of experimental and control class samples). Figure 2 shows the effect sizes of all studies. The results of the main analysis showed that there was significant effectiveness in implementing a multi-contextual approach to students' mathematical abilities (gRE= 0.6534; 95% CI [0.5102; 0.7967]; p <0.0001). The summary is 0.6534; when compared to Cohen's classification, the value falls into the strong category. Therefore, it can be concluded that there is a success in the effectiveness of mathematics learning by using a multi-contextual approach to students' mathematical abilities.

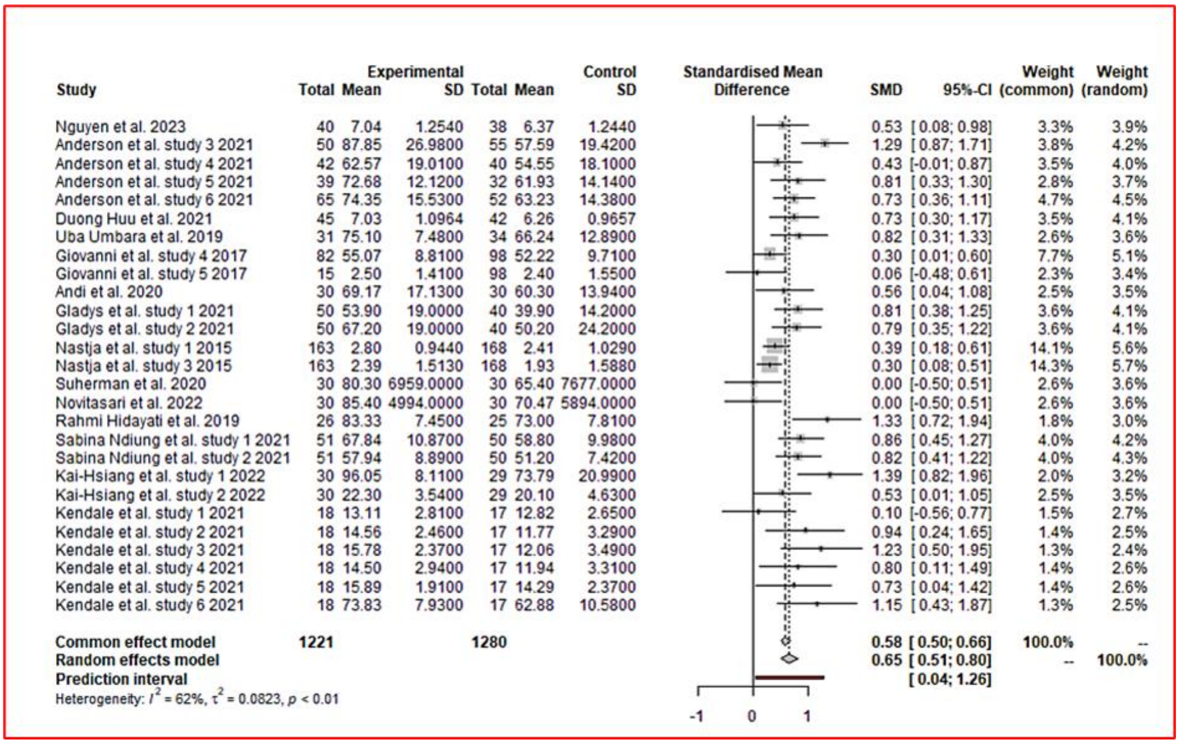

Figure 2. Plot Forest Research

The magnitude of heterogeneity is very important in meta-analysis because it can provide information about the extent of variation or difference between the results of studies that have been combined. Table 3 presents the results of the analysis of heterogeneity measurements of 27 studies. The Restricted Maximum Likelihood (REML) estimator is used to calculate the parameter of heterogeneity tau^2 (τ2) by maximizing the constrained likelihood function. This is done to avoid bias that may arise from the over-adjustment that can occur with MLE. By limiting this information, REML can provide estimates.

Table 3 provides information magnitude $\tau 2$ = 0.0823 indicating that the degree of heterogeneity is moderate among the results of the analyzed studies. This means there is significant variation among study results, but not very large. While τ = 0.2869 It gives a measure of the standard deviation of the size effect, which also indicates a moderate degree of heterogeneity. Supported by magnitude Q = 68.05; $p<0.0001$. This indicates the presence of significant heterogeneity among the study results.

Table 3. Result of Quantifying Heterogeneity Analysis

Model Random Efect	
Q	68.05
N	27
Df	26
τ^2 [95%-CI]	0.0823 [0.0301; 0.2234]
τ [95%-CI]	0.2869 [0.1734; 0.4727]
I^2 [95%-CI]	61.8% [42.0%; 74.8%]
H [95%-CI]	1.62 [1.31; 1.99]
Q	68.05

p-value	< 0.0001

Next, to test whether there is publication bias or not, a funnel chart can be taken into account. Figure 3 presents the funnel diagram obtained in this study.

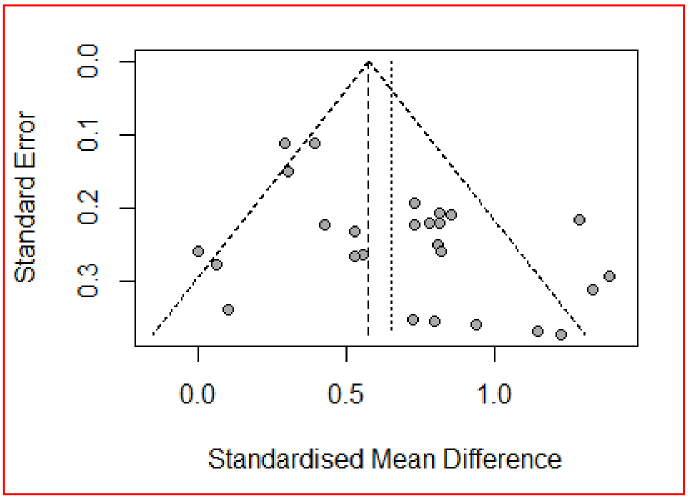

Figure 3. Research funnel plot

As can be seen in Figure 3, the size distribution of the effect is not perfectly symmetrical. It was As can be seen in Figure 3, the size distribution of the effect is not perfectly symmetrical. It was therefore decided to analyze any publication bias using statistics from Rosenthal's fail-safe N (FSN). Table 4 summarizes the findings of the N test calculation.

Table 4. FSN statistical calculation result

Refractive conditions Z value for observed studies	13.86
P values for observed studies	0.0153
Alpha	0.05
Tails	2
Z value for alpha	8.94
Number of studies observed	27
FSN	176.3057

From the results of data analysis, using R studio software, Rosenthal's safe N value is 176.3057. Based on the formula of Mullen et al. (2001) then 176.3057 / (5 * 27 + 10), the result of the calculation is 1.215. It was found that this figure is higher than 1. Based on the results of the calculations, the research study did not experience bias in publishing its findings.

Since the diverse findings in the meta-analysis, it is necessary to analyze the moderator variable, which is thought to have an impact on how dependence and independent variables relate to each other (Arik, S., & Yilmaz, 2020). 27 effect measures derived from 14 separate studies were analyzed with moderator variables such as sample size, differences in education levels, learning combinations, and geographic areas of multi-contextual approaches implementation to mathematics learning in schools.

Table 5. Summarizing the findings of this study

Category	Group	Hedge's g	Heterogenity			Decision
			(Q_b)	df(Q)	P	
Sample Size	50 or less	0.8083	2.58	1	0.1082	accept H0
	51 or over	0.6256				
Educational stage	Primary school (PS)	0.5484	9.11	2	0.0105	Reject H0
	Junior high school (JHS)	0.6931				
	Senior high school (SHS)	0.7398				
combination of learning	Math +RME	0.8134	25.72	4	0.0000	Reject H0
	Math +Ethnomathematics	0.4490				
	Math + technology	0.8497				
	Math + environmental	0.3446				
	Math + PBL	0.5297				
Geographical region	Indonesia	0.6972	25.97	6	0.0002	Reject H0
	Liverpool	0.2502				
	Vietnam	0.6361				
	Zimbabwe	0.7999				
	Slovenia	0.3446				
	Taiwan	0.9501				
	Caribbean	0.8083				

Table 5 shows the moderators' findings, including the four categories examined. First, the sample size variables were divided into two groups, namely ≤ 50 and ≥ 51. Showing the mean effect size of the two groups did not explain the statistically significant difference (Qb = 2.58; p = 0.1082). Although the mean effect size of the study with a sample number of ≤ 50 (g = 0.8083; p < 0.0001) was higher than ≥ 51 (g = 0.6256; < 0.0001) the difference was not significant. This indicates that the sample size has no impact on the success profile of the multi-contextual mathematics learning approach.

Second, the education level variables are divided into three groups: elementary, junior high, and high school. Table 5 shows the average effect sizes of the three groups differed significantly (Qb = 9.11; p = 0.0105). This indicates that education level has an impact on the success profile of the multi-contextual mathematics learning approach. In the three groups of education levels, the highest success impact at the high school level (g = 0.7398; p < 0.0001) when compared to the elementary level (g = 0.5484; p < 0.0001) and junior high school (g = 0.6931; p < 0.0001).

Third, the combination of mathematics learning resulted in five groups: Math +RME, Math + Ethnomathematics, Math + technology, Math + environmental, and Math learning + PBL. Table 5 shows the average effect sizes of the five groups were significantly different (Qb = 25.72; p = 0.0000). This indicates that combining mathematics learning has an impact on the success profile of multi-contextual mathematics learning approaches. Learning success is more impactful if mathematics is coordinated with technology approaches (g = 0.8497; p < 0.0001) and Realistic Mathematics Education (g = 0.8134; p < 0.0001) than applying a combination of mathematics learning with the environment (g = 0.3446, p < 0.0001), mathematics with PBL (g = 0.5297; p = 0.0339), or mathematics with Ethnomathematics (g = 0.4490; p = 0.0135).

Finally, based on the geographical region category, the variables were divided into seven groups of countries where the study was conducted: Indonesia, Liverpool, Vietnam, Taiwan, Slovenia, Zimbabwe, and the Caribbean. Table 5 shows the mean effect size explaining the significant difference between groups (Qb= 25.97; p = 0.0002). Taiwan had the highest impact (g = 0.950; p = 0.0274) compared to other countries: Caribbean (g = 0.8083; p < 0.0001), Zimbabwe ($g = 0.7999$; $p < 0.0001$), Indonesia ($g = 0.6972$; $p < 0.0001$), Vietnam ($g = 0.6361$; $p < 0.0001$), Slovenia ($g = 0.3446$; $p < 0.0001$), and Liverpool ($g = 0.2502$; $p = 0.0587$).

Discussion

We discuss the main findings of the study and their implications for practice and research in the same field. First, we will discuss the aggregate effect of using a multi-contextual approach on students' mathematics learning achievement. Next, we will discuss the impact of moderator variables on the effect of using a multi-contextual approach on students' mathematics learning achievement. Our first research question examines whether learning using a multi-contextual approach is more effective than traditional classroom learning (without a multi-contextual approach) on students' mathematics learning achievement. The results show a substantial and statistically significant difference ($d = 0.65$, $p < .001$), indicating that using a multi-contextual approach leads to significantly higher mathematics learning achievement than traditional or no multi-contextual approach. Based on these results, the effect of using a multi-contextual learning approach on students' mathematics learning achievement is highly satisfactory. This finding supports previous individual studies (e.g., (Juandi et al., 2022); (Gasiewski et al., 2012); (Sumirattana et al., 2017). Therefore, although some individual studies claim that the mathematics learning approach is ineffective (Yeh et al., 2019), we strongly recommend mobile learning as an alternative to improve students' mathematics skills.

Mathematical reasoning occurs when students observe a pattern (especially in a contextual problem), make generalizations and conjectures of interrelationships between mathematics, examine conjectures, construct mathematical arguments, and validate a conclusion (Lady et al., 2018); (Haji et al., 2019). The findings of this study are consistent and strengthen the results of the meta-analysis conducted by Juandi, Kusumah, and Tamur (Juandi et al., 2022a) which provides a success profile of the RME approach, previous research that supports others with a contextual approach in the form of PBL also explains the success profile of mathematics learning (Dochy et al., 2003); (Yunita; et al., 2022). The findings of this study are also consistent with the results of a meta-analysis conducted by Christopher (Rakes et al., 2020). They found that the use of technology integrated into pedagogy will have a significant impact in emphasizing the concept of mathematics education so that it has an impact on increasing students' mathematical abilities. The findings of Prahmana et al. support the success profile of mathematics learning approaches in collaboration with ethnomathematics (Prahmana et al., 2020); (Risdiyanti & Indra Prahmana, 2020).

The resulting analysis (see Figure 2) found that the study's overall effect size was measured at 0.65 based on a randomized effects model, indicating that implementation of the success profile of a multi-contextual math learning approach had a strong positive effect on students' math ability. This can be achieved because multi-contextual mathematics learning approaches such as RME, Ethnomathematika, technology, and PBL, utilize the surrounding environment allowing students to collaborate, discuss, think, and find solutions to real-world problems (Phan et al., 2022), (Makonye, 2014), (Prahmana & Istiandaru, 2021). The results showed that students in the experimental group who were ranked 15th were more or less equivalent to the control group who were ranked sixth. The findings are in line with Tamur having examined 72 studies on the impact of RME on Indonesian students' math skills and reported an overall effect size of 1.10 (Tamur et al., 2020). This finding is not much different from previous meta-analyses that game-based learning models are effective in math learning achievement (Irma Risdiyanti et al., 2019); (Benavides-Varela et al., 2020); (Syafriafdi et al., 2019). Although the number and search for this analysis differed from previous studies, it showed very similar results, a fact that shows the success of mathematics learning collaborates with several contextual approaches.

It was seen that all four moderating factors had an impact on the overall effect size of the study. The summary of outcomes illustrated in Table 5 shows a strong relationship between the effectiveness of multi-contextual math learning approaches and sample size. The combined effect size for the sample group ≤ 50 differed significantly from the combined effect size for the sample group ≥ 51. The effect of the study group on a sample of ≤ 50 was stronger compared to a sample of ≥ 51. These results encourage education practitioners to consider sample size in the implementation of subsequent applications of multi-contextual mathematics learning approaches.

Although previous meta-analyses showed homogeneity of overall effect sizes between study groups conducted in elementary, middle, and high school, such results Tamur et al., (2020) This study showed different results. This study descriptively found that the effectiveness of learning approaches at the SMA (Senior High School) level was higher than that of elementary (elementary school) and junior high school (junior high school), as seen from the stronger combined effect size in high school. However, these results are in contrast to research conducted by Chen, Shih, & Law (2020), which showed that the effect size of the study at the university level (ES = 0.14) was lower than at the elementary school (ES = 0.67) and secondary school (ES = 0.43) levels (Chen et al., 2020).

It can be concluded that although the high school learning approach showed higher effectiveness in the context of this study, there were variations in the effect size based on different levels of education, indicating the need for an approach tailored specifically for each level of education. This is possible due to the first factor, curriculum, and subject matter, where mathematics subject matter in high school is often more complex and abstract, so the application of contextual approaches may have a clearer impact in understanding these concepts (Dulama & Magdas, 2014); (Liburd & Jen, 2021); (Nguyen et al., 2020). Second, teachers in high school may have more experience or expertise in integrating contextual approaches to mathematics teaching than teachers in elementary and junior high schools. Therefore, more training is needed for teachers at elementary and junior high school levels (Arik, S., & Yilmaz, 2020); (Makonye, 2014).

Finally, there are differences in the effects of applying a multi-contextual mathematics learning approach on students' mathematics abilities in terms of the type of instrument used in each study. Studies that used measurement instruments developed by researchers had stronger effects compared to other measurement instruments. Our meta-analysis identified 5 studies that used researcher-developed measurement instruments (e.g., (Ndiung et al., 2021); (Liburd & Jen, 2021); (Sunzuma et al., 2021). It appears that measurement instruments developed by researchers are more relevant to the content and learning processes experienced by students. Therefore, it makes sense that studies using researcher-developed measurement instruments report stronger effects compared to other instruments. These findings need to be considered by other researchers when conducting empirical studies on this topic in the future.

The implications of this meta-analysis study systematically synthesize the effects of mobile learning on students' mathematics abilities. This study reveals that mobile learning has a strong impact on students' learning achievement in mathematics. This indicates that mathematics learning by applying various contextual approaches is highly recommended as an alternative to improve students' learning achievement. This study also reveals that the effectiveness of applying various contextual approaches to students' mathematics abilities is influenced by academic level, combination of learning, and research location. However, the effectiveness of the multi-contextual approach is not influenced by sample size. The multi-contextual learning approach appears to be more effective when applied at the secondary school level. However, mobile learning is less effective when applied at the elementary school level. Another interesting and important finding is that mathematics subjects are more effective when combined with RME and technology compared to PBL, ethnomathematics, and environmental approaches. These important findings can be a reference or consideration for researchers and practitioners interested in implementing various approaches that can be collaborated with contextual-based mathematics approaches in the context of strengthening literature and best practices in mathematics learning

CONCLUSION

This meta-analysis revealed that multi-contextual mathematics learning approaches have a strong and statistically significant impact on students' mathematical abilities ($g = 0.6534$; $p < 0.0001$). The most effective outcomes were observed in learning environments that combined mathematics with technology and Realistic Mathematics Education (RME), particularly at the secondary school level. These findings challenge conventional one-size-fits-all pedagogies and open new discussions on the need for adaptive, context-sensitive strategies in mathematics instruction.

This study contributes to the field by reinforcing the positive effects of contextual learning on mathematical achievement while highlighting the moderating role of educational level, instructional model combinations, and geographic context. It introduces an integrative perspective that aligns mathematics education with 21st-century demands—emphasizing the relevance of real-life contexts, cultural inclusivity, and technological integration. These insights enrich ongoing scientific discussions on how to improve mathematical literacy through innovative and culturally grounded pedagogies.

Despite its robust synthesis, this meta-analysis is limited by the scope and quality of included studies, particularly in terms of sample sizes and regional representation. The findings are also constrained by the availability of moderator data such as gender and age, which were inconsistently reported. Therefore, future research should expand the dataset with more diverse and larger samples, as well as examine additional moderating variables to provide a more comprehensive understanding of the effectiveness of multi-contextual mathematics instruction.

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