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The Meta-Analysis of Innovative Mathematics Learning Toward the Mathematics Ability in Various Countries

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ABSTRACT

This meta-analysis examines the impact of innovative mathematics learning interventions on students' mathematical abilities across various countries and educational levels. The study aims to quantify the effectiveness of these interventions and highlight their relevance in diverse educational contexts. Research data were collected from Scopus-indexed articles published between 2018 and 2022. Following strict inclusion and coding criteria, 102 articles were initially identified, of which 81 articles with 82 independent studies were screened. After further refinement, 31 independent studies were included in the final analysis. Meta-analysis methods were used, with mean effect size values serving as the primary metric for evaluating the interventions' impact. The analysis yielded a summary effect size of 74.960, indicating a substantial positive impact of innovative mathematics learning interventions on students' mathematical abilities. This effect was observed consistently across various educational levels and countries, underscoring the effectiveness of such strategies in enhancing mathematical proficiency. These findings underscore the critical role of innovative learning interventions in improving mathematics education globally. They provide empirical support for incorporating such strategies into curricula to address educational disparities and enhance learning outcomes. The study concludes that innovative mathematics learning interventions significantly improve students' mathematical abilities across diverse contexts. Further research is recommended to explore the long-term impacts and contextual factors influencing the efficacy of these interventions.

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1. INTRODUCTION

Mathematics plays an important role in education because it develops logical, analytical, and problem-solving skills essential in everyday life. These skills help students think systematically, recognize patterns, and make the right decisions in complex situations (Çelik & Özdemir, 2020; Oco, Jade, Sabasaje, & Oco, 2023). By mastering mathematics, students are prepared to face future challenges, become more adaptive, creative, and able to face problems that require innovative solutions (Cardino & Ortega-Dela Cruz, 2020). Mathematical abilities are important for students to determine life success (Deda, Disnawati, Ekawati, & Suprapto, 2024; Liang, Yin, Kang, & Wang, 2022). The ability can estimate not only students' future mathematical achievement but also their level of understanding of science and other ability (Liang et al., 2022). Learning mathematics develops students' mathematical ability as a goal of learning mathematics (Hendriana, Slamet, & Sumarmo, 2014). Therefore, by developing mathematical ability, students could improve their academic performance and work in the future.

Currently, researchers explore the potential of mathematical learning interventions to enhance quality and learning outcomes. The strategy for cultivating quality and learning outcomes is to motivate students to explore mathematical ideas so that they can improve their mathematics ability (Qohar & Sumarmo, 2013). Interventions in the learning process have an effect on student academic activity (Kuku & Adeniyi, 2020). As students participate more actively in the classroom interaction between students and teachers becomes more effective and dynamic, and provides a positive impact on student learning outcomes. Mathematical ability is a prerequisite for further learning mathematics, and is important for student achievement in further learning (Qohar & Sumarmo, 2013). Therefore, mathematical ability are important for students in cultivating their quality and learning outcomes and increasing their motivation to conduct mathematics exploration.

Teachers serve as directors and facilitators in the learning process. In the learning process, teachers should monitor students' circumstances and ability (Saleh, Prahmana, Isa, & Murni, 2018). Over time, students identify areas for development and enhancement in mathematics learning (Ulya, Sugiman, Rosnawati, & Retnawati, 2024). Eventually, mathematical ability is an important aspect of mathematics learning that has a significant impact on student learning achievement. Teachers can help students improve their mathematical ability and achieve student learning outcomes by providing fun and effective mathematics learning interventions.

Various studies in Indonesia and in other countries, are concerned with the impact of mathematical learning interventions on student mathematics ability. These studies show that interventions in learning mathematics can enhance students' mathematical ability (Podkhodova, Snegurova, Stefanova, Triapitsyna, & Pisareva, 2020; Son, Darhim, & Fatimah, 2020). However, many teachers in Indonesia are not habituated with the results of previous research. Teachers in Indonesia are more likely to employ a teacher-centered learning approach. Students' mathematical ability will improve when teachers select models, methods, and learning strategies that optimize both the learning process and the level of evaluation.

Innovative mathematical learning interventions have a general impact on students' math ability, as proven by research results. The results show that contextual learning models can improve students' mathematical abilities (Surya, Putri, & Mukhtar, 2017). The presence of media or teaching materials can support the chosen learning model, facilitating students in their learning process and enhancing their mathematical ability. Implementing a problem-based learning model with GeoGebra, multimedia (Far'i, Fahrurrozi, & Marhamah, 2023), information and communication technology (Tanjung, Baharuddin, Ampera, Farihah, & Jahidin, 2022), and so on can improve students' mathematical ability. It shows that interventions in learning mathematics through innovative learning have a positive impact on improving students' mathematical abilities. Various studies found that mean mathematical ability increased after intervention. However, these findings have not been generalized, so the effectiveness of innovative mathematical learning interventions in various countries in terms of mathematical ability has not yet been determined.

Innovative learning, such as constructive, active, and technology-based approaches, is important in improving students' mathematical abilities. Constructivism emphasizes learning as an active process in which students construct knowledge based on their experiences, allowing for a deeper understanding of mathematical concepts (Rokaya, 2021). Active learning involves students' active participation in the learning process through discussions, problem-solving, and group work, proven to be effective in improving critical thinking and mathematical problem-solving skills (Vale & Barbosa, 2023). Meanwhile, technology-based approaches allow for the visualization of abstract mathematical concepts and provide interactive learning experiences (Bright, Welcome, & Arthur, 2024).. This meta-analysis study shows that the implementation of these strategies across countries consistently improves mathematical abilities, reflecting the importance of innovative approaches in mathematics learning.

This research investigated the effectiveness of innovative mathematical learning interventions for improving student mathematics capabilities in various countries, by conducting investigations into various previous studies. Overall, this meta-analysis can serve as a roadmap that shows effective strategies for developing students' mathematical skills globally, enabling evidence-based policy adaptation, and fostering international synergies in educational innovation. Based on the issue, the study examined the effectiveness of innovative mathematical learning interventions in various countries for student mathematics capabilities at all levels of education through meta-analysis research during the period 2018–2022. The results of this study are expected to provide evidence-based guidance for educators, researchers, and policymakers to improve mathematics education practices. Thus, this study identifies innovative approaches that are effective and support global education policies that are oriented toward improving students' mathematics abilities.

2. METHODS

A meta-analysis is a study that examines pertinent research from sources by statistically reviewing the research (Rahman et al., 2023; Suharyat, Ichsan, Santosa, Aprilisia, & Yulianti, 2022). This meta-analysis aims to assess the impact of innovative mathematics learning interventions on students' mathematical abilities across various educational levels and countries. The study took articles with research data that described students' mean mathematical ability after receiving innovative learning interventions.

2.1. Data Sources and Search Strategy

This research applies a meta-analysis design by calculating the effect size with a random effect model. The collected data were from the published research documentation results from Scopus-indexed articles and proceedings. The literature review went systematically to determine the mathematical ability from the Scopus database. The applied keywords were mathematics ability, mathematics skill, and mathematics learning. The analyzed documents consisted of online articles and proceedings. The filters applied in this study include the year of publication (2018–2022) and contain information on the number of samples, average, standard deviation, and range of mathematical ability values in innovative learning. The selection of articles indexed by Scopus is based on Scopus's reputation as one of the largest and most trusted scientific databases with international coverage. Scopus provides articles that have gone through a peer-reviewed process and have high-quality standards.

2.2. Inclusion and Exclusion Criteria

Inclusion criteria were set to ensure the quality and relevance of the included studies. The studies included were quasi-experimental, experimental, or other quantitative studies that measured the effectiveness of innovative mathematics learning on students' mathematical abilities. The studies' results must meet data requirements, namely reporting mean scores, standard deviations, and sample sizes. These data are important to allow for accurate calculation of effect sizes.

Exclusion criteria were applied to eliminate studies that did not fit the purpose of this meta-analysis. Descriptive, qualitative, or case studies were excluded because they did not allow for objective comparisons of innovative and conventional learning effectiveness. Studies that did not report mean scores, standard deviations, or sample sizes were also excluded because the absence of these data hampered the calculation of effect sizes.

The criteria for the availability of mean scores, standard deviations, and sample sizes are very important in this study because they are used to determine effect sizes. Calculation of effect sizes is useful for evaluating the effectiveness of mathematics learning interventions on students' mathematical abilities at various levels of education quantitatively.

2.3. *Data Extraction and Codings*

The data extraction process in this meta-analysis was carried out systematically to collect important information from each study that met the inclusion criteria. Data from each article were extracted and coded into a uniform format to ensure consistency and facilitate analysis. The main variables coded include the year of publication, sample size, mean effect size, score range, level of education (e.g., primary, secondary, or tertiary), country where the study was conducted, and type of intervention used in innovative mathematics learning, such as project-based learning, use of technology, or collaborative approaches, and so on. The research team carried out the coding process manually to maintain the accuracy and consistency of the data collected. To facilitate coding, it can be arranged as in Table 1.

Table 1. Studies within the Meta-Analysis

No	Name (Years)	Sample size	Mean	Score range	Educational level	Country	Intervention
1	(Fani & Rosnawati, 2018)	127	82.73	0-100	Junior High School	Indonesia	Scientific approach with scaffolding and interactive media toward the mathematics learning outcomes
⋮ etc							

2.4. *Sample Determination*

The researchers collected 102 articles based on similar criteria and results. The researchers found 81 articles with 82 independent articles based on the coding criteria. The incomplete articles such as having no data range, standard of deviation, and sample size, were excluded from the research. After the coding, the researchers found 30 relevant articles based on the inclusion and only 1 article with an independent sample. Therefore, the researchers found 31 independent articles as the research samples. Figure 1 shows the sample determination briefly.

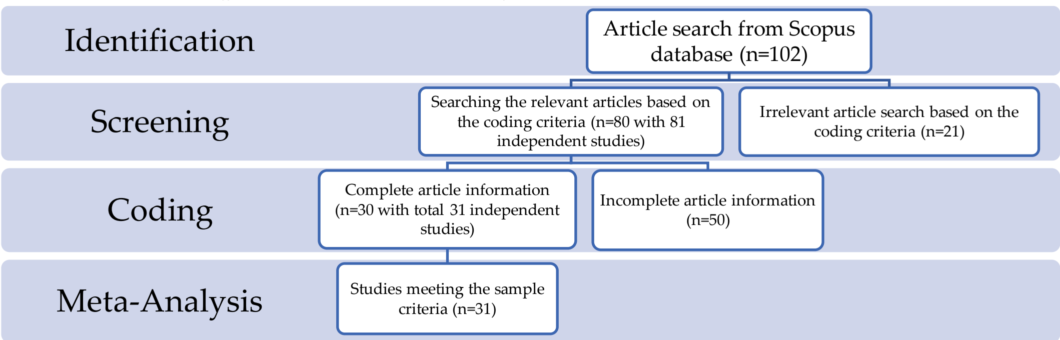

Figure 1. The schemes of the analyzed articles

2.5. *Data Analysis*

The applied data analysis technique was Meta-analysis with Microsoft Excel and Jeffrey's Amazing Statistics Program (JASP). Microsoft Excel is useful for collecting the effect size (ES), equalizing the ES scale by conversion, and calculating the Standard Error (SE) for each study. The JASP is useful to determine the overall effect size and the aggregate. Microsoft Excel and JASP were chosen as the analysis software in this meta-analysis because they have complementary advantages. Microsoft Excel was used for initial data organization, such as entering and managing data extracted from each study and facilitating simple data manipulation and basic calculations. Meanwhile, JASP was chosen because of its ability to perform advanced statistical analyses required in meta-analysis, such as effect size calculation, heterogeneity analysis, and data visualization. JASP also provides an easy-to-use interface and open-source statistical tools specifically designed for evidence-based data analysis, thus supporting meta-analysis effectively. The statistical techniques to explain the data were: (1) heterogeneity test (Random Effect model to estimate the effect size mean if the results are heterogeneous while Fixed-Effect model if the data were homogeneous; (2) determining the effect size aggregate or summary effect; (3) arranging and interpreting the forest plot; and (4) checking the publication biases using funnel plot and Egger's test (Retnawati et al., 2018).

3. FINDINGS AND DISCUSSION

3.1. *Findings*

This research evaluated the effects of innovative mathematics learning in various countries and levels, starting from public Primary School (PS), Junior High School (JHS), Senior High School (SHS), and University (U). The results of this meta-analysis indicate that innovative mathematics learning interventions overall have a significant positive effect on students' mathematics abilities at various levels of education, with an average effect size of 74.960. The heterogeneity found among studies indicates considerable variation in the effectiveness of the interventions. Table 1 shows the analyses of the 31 studies.

Table 2. Studies within the Meta-Analysis

No	Name (Years)	Intervention	Research sites	ES	SE
1	(Fani & Rosnawati, 2018)	Scientific approach with scaffolding and interactive media	Indonesia	82.73	0.997
2	(Hutajulu & Wahyudin, 2018)	Metacognitive learning	Indonesia	57.792	1.342
3	(Jamhari & Wongkia, 2018)	Concrete manipulative-based learning cycle unit	Thailand	79	12.084
4	(Putranto & Marsigit, 2018)	Peer-tutoring learning with realistic mathematics education	Indonesia	68.71	1.952
5	(Suharti, Latuconsina, Tasril, Sriyanti, & Halimah, 2018)	Realistic mathematical learning	Indonesia	85.91	0.81
6	(Syamsuddin & Istiyono, 2018)	Contextual teaching and learning	Indonesia	81.62	1.333
7	(Amrina & Rosnawati, 2019)	Realistic mathematics education	Indonesia	86.32	1.297
8	(Arilaksmi, Ummah, & Utomo, 2019)	The implementation of mathematical comics with an Indonesian culture	Indonesia	66	5.366
9	(Holisin, Ainy, & Wikanta, 2019)	The OSCAR learning	Indonesia	55.12	3.33

No	Name (Years)	Intervention	Research sites	ES	SE
10	(Ilyas, Ma'Rufi, & Basir, 2019)	Cooperative based emotional intelligence learning	Indonesia	88.67	1.115
11	(Inda & Widjajanti, 2019)	Modified discovery learning with aptitude treatment interaction	Indonesia	67.49	1.543
12	(Ityavzua, Ofoegbu, Muhammad, & Jimin, 2019)	The learning with virtual mathematics laboratory	Nigeria	70.17	0.803
13	(Lestari, 2019)	Learning with problem-solving approach	Indonesia	61	1.686
14	(Miliyawati, Herman, & Turmudi, 2019)	Problem-based mathematical habits of mind	Indonesia	55.9	1.052
15	(Ningsih, 2019)	Think pair share cooperative learning	Indonesia	65.54	2.147
16	(Taufik et al., 2019)	The implementation of mathematics learning materials based on contextual teaching and learning	Indonesia	75.89	1.456
17	(Zin, Rosli, & Saleh, 2019)	Online learning environment	Malaysia	70.25	2.619
18	(Darma, Karma, & Santian, 2020)	The implementation of mathematics-based blended learning book	Indonesia	48.33	1.603
19	(Gumilar, Siti Afrian, Pramiarsih, & Widjadjani, 2020)	The implementation of improving method	Indonesia	75.82	1.208
20	(Pasaribu & Suyanto, 2020)	The STEM learning	Indonesia	84.132	1.637
21	(Ridha, Pramiarsih, & Widjajani, 2020)	The implementation of GeoGebra	Indonesia	72.472	2.648
22	(Rozana, Makmuri, & Hakim, 2020)	The problem-based learning	Indonesia	85.071	1.688
23	(Rozana et al., 2020)	The thinking talk write learning	Indonesia	84.496	1.674
24	(Sulasteri, Suharti, Amri, Halimah, & Kusumayanti, 2020)	The Kumon learning	Indonesia	87.08	0.913
25	(Suryanti, Arifani, & Sutaji, 2020)	The implementation of augmented reality	Indonesia	83.915	1.232
26	(Alimuddin, Mulbar, & Rahmadani, 2021)	Discovery learning with scientific approach	Indonesia	91.333	0.975
27	(Alimuddin, Ruslan, & Nashrullah, 2021)	The ICCACRE learning	Indonesia	72.5	0.85
28	(Andriani, Ali, & Jarnawi, 2021)	The implementation of STEM	Indonesia	65	1.894
29	(Hadiyanti et al., 2021)	The implementation e-module with collaborative project-based STEM	Indonesia	76.67	9.017
30	(Jusmawati, Satriawati, Irman, Rahman, & Arsyad, 2021)	The creative problem-solving learning based on android	Indonesia	89.55	1.769

No	Name (Years)	Intervention	Research sites	ES	SE
31	(Sumilat, Tuerah, & Setiawan, 2022)	The implementation of online media	Indonesia	88.46	1.518

Figure 2 displays data on the mathematics learning interventions that produced the highest mathematics performance across the studies analyzed. This visualization makes it easy to identify the interventions with the most significant impact and the educational contexts that support their effectiveness.

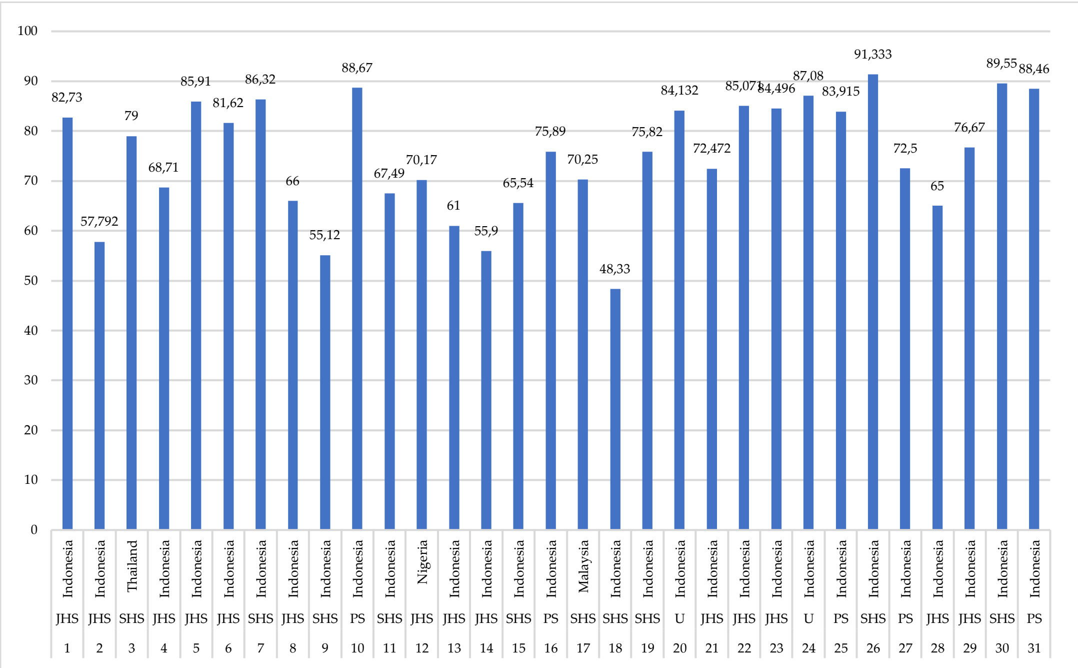

Figure 2. Distribution of effect sizes across different types of interventions

In implementing mathematics learning interventions, students responded more positively to visual and interactive approaches, which strengthened their understanding of basic mathematical concepts. At the secondary education level, interventions involving collaborative learning and complex problem-solving strategies had a greater impact. These findings indicate that the effectiveness of interventions depends not only on the type of intervention but also on the students' educational level.

3.1.1 Heterogeneity Test

The test of this research used the JASP software. The test involved the Q-statistic method. The table of fixed and random effects provides the Q-P values. Table 3 and Table 4 briefly show the heterogeneity results.

Table 3. Heterogeneity Test

Fixed and Random Effects			
	Q	df	p
Omnibus test of Model Coefficients	1204.186	1	< .001
Test of Residual Heterogeneity	2165.044	30	< .001

Note. p -values are approximate.

Note. The model was estimated using the Restricted ML method.

Table 3 shows the df or the degree of freedom, the numbers of the analyzed studies subtracted with 1. This meta-analysis found 31 independent studies with a pdf of 30. The Q and p-value values on the residual heterogeneity test line infer heterogeneity. The analysis results showed a Q value of 2165.044 and a p-value of < 0.001, meaning a p-value < α (α = 0.05). The evaluation values show the effect size of the 31 studies are heterogeneous. Therefore, the estimated mean effect size of this meta-analysis requires the random effect model for accurate results.

Table 4. Residual Heterogeneity Estimates

		95% Confidence Interval	
	Estimate	**Lower**	**Upper**
τ^2	137.199	83.866	240.737
τ	11.713	9.158	15.516
I^2 (%)	98.673	97.847	99.239
H^2	75.340	46.442	131.442

The residual heterogeneity estimates obtain an I^2 of 98.673. The I^2 range is between 97.847 and 99.239. This I^2 value of 98.7% indicates the effect size of the studies is not homogeneous or heterogeneous. Sampling errors or differences in effect sizes between the studies cause this heterogeneity. Therefore, in an effort to prevent the inaccuracies of the random effect model, the summary effect interpretation applied the random effects model.

A high I^2 value indicates significant heterogeneity among the studies analyzed. A high I^2 value implies that the results of each study are not fully comparable due to variations in the type of intervention and different characteristics. Therefore, using a random effects model is appropriate because this model assumes that differences in results between studies come not only from sample variability, but also from differences that may occur due to the unique characteristics of each study. With a random effects model, the average effect estimate is more flexible because it takes into account the variability between studies, resulting in conclusions that are more relevant to a wider population and diverse conditions.

Table 4 presents the coefficient table, displaying the aggregate ratio from 31 studies on the impact of innovative mathematical learning interventions on student mathematics abilities. Table 5 shows the aggregate of the effect size.

Table 5. Summary Effect (Aggregate Effect Size)

Coefficients						
					95% Confidence Interval	
	Estimate	**Standard Error**	**z**	**p**	**Lower**	**Upper**
intercept	74.960	2.160	34.701	< .001	70.726	79.194

Note. Wald test.

Table 5 shows that the random effect model yields a summary effect of 74.960, a standard error of 2.160, and a z-value of 34.701. The p-value is less than 0.05. These findings indicate that the mean effect size is significant. This mean effect size meets excellent criteria. The forest plot shows the outcome of this aggregate ratio. The forest plot presents a corresponding aggregate ratio to Table 4, with a lower limit of 70.726 an upper limit of 79.194, and confidence intervals at a significance of 95%.

3.1.2 Publication Biases

To identify bias in publications, one must evaluate publication bias. A qualified meta-analysis must be free from biases. Figure 3 illustrates signs of this bias in the plot funnel.

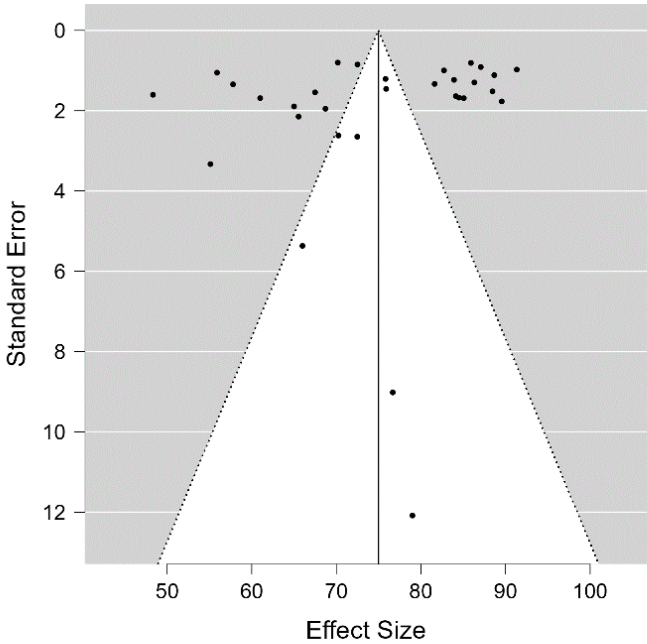

Figure 3. Funnel Plot

The X-axis on the plot funnel describes the size effect value of each study, while the vertical line in the middle represents the mean size effect of all the studies used in this meta-analysis. The distribution of points on the plot funnel reflects the study's size effect distribution based on standard error. The Y axis indicates the standard error or standard error of the studies. Positions of the distribution points of the size effect that are increasingly below indicate a high standard error. Figure 3's plot funnel result demonstrates a tendency toward symmetry, suggesting the absence of publication bias.

Because the plot funnel solely relies on visual judgment and subjective impressions, the results cannot serve as a solid foundation for proving that the plot is symmetrical or asymmetric (Zhang, Huang, Wu, Li, & Liu, 2019). Table 5 displays the correlation test results, revealing the publication bias in addition to the plot funnel.

The plot's funnel visual shows no publication bias. However, this visualization is not strong enough as a basis for claiming plot symmetry. The solely judgment based on visuals is seemingly subjective. The correlation test results, in addition to the plot funnel, can analyze the publication bias. Table 6 presents the rank correlation result.

Tabel 6. Rank Correlation

Rank correlation test for Funnel plot asymmetry		
	Kendall's τ	**p)**
Rank test	-0.174	0.175

Table 6, the rank correlation test results, serves as a reference for the assessment of publication bias. The plot funnel is considered symmetrical if the p-value is greater than 0.05. Table 6 demonstrates that the plot funnel is symmetrical because the p-value is 0.175 ($p > 0.05$). The test revealed no publication bias in this meta-analysis study. The absence of bias in this meta-analysis indicates that the reported results come from various studies, thus strengthening the robustness of the findings. Without publication bias, the results of this meta-analysis are more reliable in representing the true effects of innovative learning interventions on students' mathematics ability. This suggests that the conclusions drawn are more stable and less influenced by the tendency to report only studies with positive or significant results, providing greater confidence that the results can be used to formulate educational policies.

3.2. Discussion

Meta-analysis offers a comprehensive assessment by analyzing quantitative data from research on students' mathematical abilities (Rahman et al., 2023). In this study, innovative learning interventions were implemented in a systematic and explicit manner. Teachers teach ways to overcome the difficulties of learning mathematics by paying special attention to the process of mathematical learning (Netson & Ain, 2020). Current results remain the same as previous research. Mathematical learning interventions have a positive influence on students' mathematical abilities (Kadir, 2017; Rahmatika & Waluya, 2023).

The findings in this meta-analysis are in line with several previous studies that also show the effectiveness of innovative learning interventions in improving students' mathematics skills, especially in an international context. Several previous studies have also found that the use of innovative learning approaches, such as problem-based and collaborative learning, significantly supports students' conceptual understanding and problem-solving skills across countries (Busaka, Umugiraneza & Kitta, 2022; Warmansyah et al., 2023). However, unlike previous studies, this meta-analysis involves more recent data coverage and focuses on variations across educational levels and countries, thus providing a more comprehensive picture of the effects of innovative learning interventions on a global scale. Several previous meta-analyses focused on a single intervention and did not focus across educational levels and countries (Alhadoor, Aldbyani, & Alshammari, 2023; Ariati, Anzani, Juandi, & Hasanah, 2022). Thus, this analysis not only confirms previous findings but also broadens insights into contextual factors that may influence the effectiveness of interventions, for example, cultural differences or curriculum approaches in each country. The educational culture of a country can influence students' and teachers' receptivity to innovative learning methods, such as how open they are to more active and collaborative learning. Curriculum policies also determine the scope and flexibility for integrating innovative strategies into mathematics teaching. In addition, the readiness of technological infrastructure plays a significant role in supporting technology-based approaches, as adequate access to digital tools and resources greatly influences the implementation and effectiveness of innovative learning.

The heterogeneity test obtained an I2 score of 98.673, or 98.7% (higher than 75%). The value indicates the heterogeneous effect size. High heterogeneity indicates variability in most measurements (Kong, Yan, Serceki, & Swanson, 2021). Thus, the researchers applied a random effect model to calculate an effect size combination (Gurka, Kelley, & Edwards, 2012; Hedges, 1983). Table 6 shows the p-value to determine the symmetrical plot funnel indication. If the p-value exceeds 0.05, the plot funnel is considered symmetrical. Egger's test also showed a p-value of 0.546, higher than 0.05, thus reinforcing that the plot's resulting funnel is symmetrical. The results demonstrate that the meta-analytic study is not biased.

The high level of heterogeneity in this meta-analysis reflects that the effectiveness of innovative learning interventions in mathematics varies substantially across different contexts. This high heterogeneity indicates that not all interventions have the same effect in every situation. The high heterogeneity in this meta-analysis was due to variations in the teaching methods used, differences in students' educational levels, and different sample characteristics, thus strengthening the credibility of the results by considering various factors that influence the effectiveness of the intervention. The implication is that the implementation of innovative learning interventions needs to consider adaptations that align with local needs and student characteristics. By understanding these contexts, educational policies can more accurately direct appropriate methods to enhance the effectiveness of mathematics learning in various environments.

The aggregate rate from 31 of these meta-analysis studies is 74,960. These values indicate that after learning innovative mathematics, students' mathematical abilities fall into the category of excellent. The results showed that innovative mathematical learning interventions could improve students' math ability. It supports research findings that indicate the significant effect of innovative learning interventions on students' mathematical abilities (Daroni et al., 2018; Dinayusadewi & Agustika, 2020; Gyanthi et al., 2023; Ulya & Rahayu, 2021).

The significant effect size indicates that innovative learning interventions have a meaningful positive impact on students' mathematics learning outcomes. This practical significance indicates that approaches such as problem-based learning, collaboration, or interactive technology not only have a statistical impact but also significantly strengthen students' understanding, problem-solving skills, and motivation in mathematics. For students, this means that the application of innovative strategies in mathematics classes can enhance their engagement and academic success. This supports the need for a broader adoption of active and contextual learning methods, which can encourage student success at various educational levels.

Such interventions facilitate students to learn independently or in groups. Students could recognize and understand plans for developing mathematical ability and creative and reflective thinking (Syarifah, Usodo, & Riyadi, 2018). These interventions foster acceptance and transfer of ability and knowledge, improving the quality of learning. This intervention also presents scaffolding to facilitate the mathematical ability of unorganized students (Damayanti & Sumardi, 2021).

Teachers have a duty to facilitate and optimize students' mathematical abilities. However, the learning planning process needs to consider the different characteristics of students. Therefore, teachers could provide specific student's intervention to their unique characteristics. Teachers should devise a mathematical learning intervention plan based on their pupils' personalities (Permata, Netson, & Ain, 2021). Teachers must promote innovative learning to improve the quality of the mathematics learning process (Vidyastuti, Effendi, & Darmayanti, 2022).

This research demonstrates that interventions in learning mathematics are innovative, enjoyable, and effective in improving the mathematical abilities of students in different countries and educational levels. This finding may encourage mathematics teachers around the world to use more creative and enjoyable learning methods in order to avoid monotonous and conventional approaches. Teachers are advised to integrate problem-based and collaborative learning methods that demonstrate the highest effectiveness in enhancing students' understanding and mathematical problem-solving skills in various contexts. Teachers are also advised to implement innovative learning strategies, such as collaborative problem-solving and interactive technologies. At the same time, policymakers are expected to provide professional training for teachers and invest in educational technology infrastructure to support the effectiveness of these approaches.

This meta-analysis study exhibits certain limitations in terms of literature collection. (a) Challenges in locating relevant articles in international journals with the outlined topics; (b) Difficulties in accessing articles from research sites located in the western hemisphere; and (c) Difficulties in obtaining articles of the same educational level. This research proposes that future researchers introduce similar research to determine whether the intervention or learning approach is most suitable for teachers. Teachers must implement new interventions in innovative mathematical learning practices in the classroom, paying attention to student characteristics and differentiation. Teachers should also assess students' mathematical abilities in order to provide feedback. Future research could also focus on the effectiveness of innovative learning interventions within specific subgroups of students, such as based on age or initial skill level, as well as testing their outcomes in various educational systems to understand the impact of context on the success of the interventions. In addition, a meta-analysis could further explore international databases such as WoS or ERIC and use more studies from countries with different educational contexts to expand the generalizability of the findings.

4. CONCLUSION

This meta-analysis research shows that innovative and enjoyable mathematics learning interventions have a significant positive effect on students' mathematical abilities, with an average effect size of 74.960, indicating a substantial improvement in students' overall mathematics performance. These findings are important for educators and policymakers to adopt student-centered learning methods in various educational contexts to enhance students' mathematical abilities and engagement. However, the limitations of this research include difficulties in finding relevant international journal articles on the topic, the research location being in the western hemisphere, and the uniformity of educational levels. Further research needs to explore specific types of interventions or long-term effects, as well as conduct studies in various educational systems to deepen the understanding of the sustainability and context of these intervention outcomes.

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