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Effectiveness of the Metacognitive-based Pedagogical Intervention on Mathematics Achievement: A Meta-Analysis

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Metacognition is a 21st-century lifelong skill and integrating this into a learning intervention is increasingly crucial to students' progress. However, studies have shown that there is a lack of empirical studies that focused entirely on the effect of metacognitive-based intervention on mathematics education. Thus, this meta-analysis examines the effectiveness of the metacognitive-based pedagogical intervention on students' mathematics achievement. From various meta-search engines, 23 out of 2341 empirical studies from 2015 to 2022 met the set of inclusion and exclusion criteria and were subsequently included in the analysis. Using Comprehensive-Meta-Analysis (CMA) software, descriptive statistics were gathered and analyzed to generate moderator analysis, heterogeneity, publication bias, forest plots, funnel plots, trim and fill method, and Hedges'g effect size. Findings showed that the overall weighted effect size was g=1.358, indicating that metacognitive-based pedagogical intervention has a significantly large and positive effect on students' mathematics achievement. Further moderator analysis showed significant differences in mathematics subject area, while the educational level and targeted learning outcomes found no significant differences. These results establish the effectiveness of using metacognitive-based pedagogical interventions in mathematics education. Findings also serve as a foundation for teachers and educators in making informed decisions on introducing a potential intervention that impacts mathematics education.

Keywords: metacognition, metacognitive-based pedagogical intervention, metacognitive strategy, mathematics achievement, meta-analysis

INTRODUCTION

The urgency to fix the challenges and disparities regarding students’ mathematics achievement is still a primary concern for educators worldwide. Educators and experts delve into this field of education to figure out the root causes of students' mathematical

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struggles and difficulties. For instance, experts conducted several studies on what metacognition could bring to students' mathematics performance. Since learning mathematics effectively requires firm knowledge and understanding of mathematical concepts and skills, it is imperative to acquire skills such as metacognition. They recognize the importance of nurturing students' innate abilities to make them self-sufficient, independent, and creative learners (Meher et al., 2021). However, in a conventional learning setup, students do not have the opportunity to regulate their learning process since teachers already define what students learn, provide learning instruction, and evaluate students' learning goals. Hence, metacognitive strategies have been gaining central importance as learning interventions. Thus, it is imperative to investigate and examine the effectiveness of metacognitive-based pedagogical instruction on improving students' mathematics achievement.

Studies have shown that students need metacognitive skills in order to actively participate in the learning process. In this regard, metacognitive-based pedagogical intervention is an instruction in response to 21st-century life-long learning skills to improve students' mathematical learning outcomes. Since the effect of metacognition is evident in several studies, researchers emphasize the importance of integrating strategies that could use metacognition in learning mathematics. For instance, Alzharani (2017) asserted that students' mathematics performance is significantly and positively affected when applying metacognitive strategy in their teaching approach. Also, Naufal et al. (2021) infused metacognition in the van Hiele model and found that it effectively improves students' geometry thinking level compared to geometry learning strategy. However, it was shown that students do not usually acquire metacognitive ability through instruction, and it is due to the limited framework and planned cognitive activities in teaching (Ahmad et al., 2018). The effectiveness of the metacognitive strategy is evident; however, it needs to be revisited to ascertain its effect on students' mathematics achievement.

Moreover, several meta-analyses and systematic reviews have been conducted on the effectiveness of the metacognitive strategy. Most of these studies focus on academic performance and science disciplines. For instance, a meta-analysis study on the impacts of the metacognitive approach undertaken by de Boer et al. (2018) found that the long-term effects were much smaller than the posttest effects. Antonio and Prudente (2021) examined ten studies and found that metacognitive instruction effectively improves students' science achievement. Camarao et al. (2021) focused on the effectiveness of metacognitive instructions through metacognitive scaffolds on physics. The same result was also demonstrated in the study of Lee et al. (2018) on 18 studies which concluded that metacognitive training positively impacts students' algebraic reasoning. In the analysis of the effects of various metacognitive strategies, Meher et al. (2021) found that brainstorming, concept mapping strategy, and the think-aloud strategy had the large effect, while others showed only a medium effect. However, Norma (2020) argues that there are instances when metacognition is detrimental to one's cognitive success. Therefore, metacognitive strategies should be reevaluated the efficacy. Although there are many methods for fostering metacognition in the classroom, not enough is known about which methods are most effective when it comes to teaching mathematics.

Relative to the previous literature, there is a lack of meta-analyses, and systematic reviews that solely focused on the empirical study of the metacognitive intervention on students' mathematics achievement. Thus, this meta-analysis was conducted to give insights into the effectiveness of the metacognitive-based pedagogical intervention (MBPI) on students' mathematics achievement. This meta-analysis will provide teachers with practical and valuable information about its effect on student mathematics performance and substantial integration and implementation of metacognitive strategies in mathematics education. This will also serve as the baseline study and foundation for educators to make informed decisions supported by evidence-based research to provide effective teaching and learning practices.

Specifically, this study sought to answer the following questions: (1) How effective is the use of metacognitive-based pedagogical intervention on students' mathematics achievement? (2) How do the effects of using metacognitive-based pedagogical intervention differ when mathematics achievement is measured in terms of: a) educational level; b) mathematics subject area; and c) targeted learning outcomes; (3) What metacognitive-based strategies have the existing studies implemented to improve students' mathematics achievement?

METHODS

Research Design

The study utilized a quantitative research design, primarily a meta-analysis research design. In this study, the meta-analysis was used to examine the effectiveness of the metacognitive-based pedagogical intervention (MBPI) on students' mathematics performance. The study followed the five steps of a meta-analysis, which include (1) definition of the research problem or hypothesis; (2) search for relevant literature; (3) extraction of data (coding); (4) application of statistical methods; and (5) and presentation of results (Borenstein et al., 2009; Duveneck, 2015; Schmidt & Hunter, 2015).

Study Search Procedures

Prior to the search and scanning of studies, the criteria for inclusion and exclusion had already been established. The relevant studies were selected from various electronic databases and web search engines such as Google Scholar, ERIC, Science Direct, Scopus, PubMed, and Crossref. Moreover, the researcher used the software program Harzing's Publish or Perish program to find the list of possible journal articles. The search started from January 2015 until July 2022, and several descriptors or keywords were strategically entered into search engines to find relevant studies. Terms such as "mathematics performance," "mathematical problem-solving," "mathematical skill," and "mathematics achievement" were entered arbitrarily and interchangeably, using Boolean operators "And" or "OR" with words "metacognition," "metacognitive-based instruction," "metacognitive instruction/instruction," and "metacognitive-strategy."

Inclusion and Exclusion Criteria

The selection process was done by selecting studies involved and closely related to metacognitive instruction/intervention in mathematics class using the paper title, keywords, and several descriptors. Moreover, the researcher scanned and identified each suitable or relevant study based on the following inclusion criteria: (1) the articles must be published from January 2015 to July 2022; (2) must have an available full text; (3) they must be written in the English language; (4) must have explicit reference to metacognitive strategies as intervention; (5) must be focused on mathematics class and students' mathematics performance as the dependent variable and learning outcomes; (3) must be empirical research and utilize an experimental or quasi-experimental pre-test, and posttest research design; (4) must include sufficient statistical data or quantitative data to allow effect size computation (e.g., mean and standard deviation). Figure 1 shows the PRISMA search process flow adapted from Page et al. (2021).

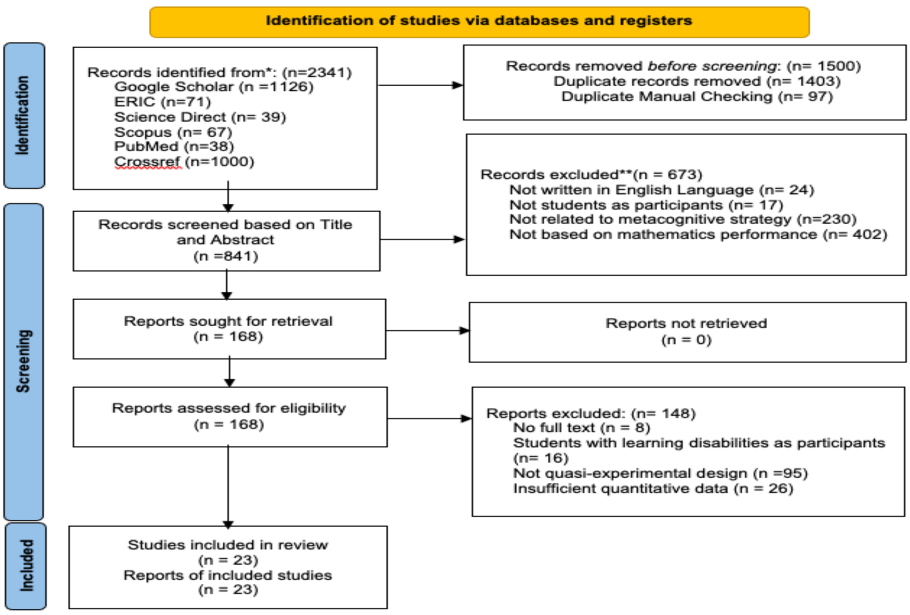

Figure 1
The PRISMA search process flow

It can be seen from Figure 1 that the researcher identified 2341 articles through database searching. Using duplication tools and manual checking,1500 studies were removed. Studies screened based on title and abstract were 841; of these studies, only 168 articles were assessed for eligibility. After the rigorous reviewing the full articles, only 23 studies met the remaining criteria, and the rest lacked the required information and quantitative data.

Coding Procedures

Relevant information from the qualified journal articles was analyzed and coded by the authors according to the following: Title of the study, author/s, publication year, publication type, relevant contents of the research, and the results. The demographic characteristics of the selected studies were analyzed based on the (a) educational level, (c) mathematics subject area, (d) and targeted learning outcomes. The study also gathered the metacognitive strategy used in the studies. Moreover, any discrepancies between authors' coding were discussed and resolved.

Effect Measures

The researcher utilized the software Comprehensive Meta-Analysis (CMA) Version 3 in organizing and analyzing the data, generating the moderator analysis, heterogeneity, publication bias, forest plots funnel plot, and calculating the effect size in the form of Hedges'g. The collected data were interpreted using the following criteria; 0.80 and above (large effect); 0.50 t0 0.79 (medium effect); 0.20 to 0.49 (small effect) and less than 0.19 (no effect) (Borenstein et al., 2014). The moderator analysis was also carried out to determine the differences between subgroups and the average sizes of different variables.

FINDINGS

Overall Effect Sizes

Based on the qualified 23 empirical studies included in the meta-analysis, a total of 2616 was identified as the sample size. Table 1 presents the frequencies and percentages of the included studies.

Table 1
Frequencies and percentages of the included studies

Variables	Frequency (n=23)	%
Education Level		
Primary	7	30.43
Secondary	11	47.83
Tertiary	5	21.74
Math Subdomain		
Algebra	3	13.04
Arithmetic	3	13.04
Geometry	4	17.39
Math Word Problems	6	26.09
Statistics and Probability	1	4.35
Not specified	6	26.09
Targeted Learning Outcomes		
Conceptual Understanding	9	39.13
Mathematical Communication	2	8.70
Mathematical Logical Thinking Ability	2	8.70
Creative Thinking Ability	2	8.70
Mathematical Reasoning Ability	2	8.70
Problem Solving Skills	6	26.09

As shown in Table 1, the majority of the studies were conducted at the secondary level (47.83%), and the least targeted participant was from the tertiary level (21.74%). The study was mainly used in math word problems (26.09%), and only one (4.35%) study in statistics and probability. However, six (26.09%) studies did not specify the subject area of the study. In terms of the targeted learning outcome, most of the studies aimed to improve conceptual understanding (39.13%), followed by problem-solving ability skills (26.09%), mathematical communication skills (8.70%), mathematical, logical thinking ability (8.70%), creative and critical thinking ability (8.70%), and mathematical reasoning ability (8.70%). Table 2 presents the findings on the overall effect size of the study.

Table 2
Overall effect size

	k	ES (g)	SE	Variance	95%CI		z	p	Heterogeneity			
					Lower	Upper			Q	df	P_Q	I^2
Fixed	23	0.841	0.04	0.00	0.76	0.92	19.99	0.00	361.96	22	0.000	93.92
Random	23	1.358	0.19	0.04	0.99	1.72	7.307	0.00				

Findings revealed that the overall weighted effect size was 1.358 using random effect model for 23 studies indicating that MBPI has a significantly large and positive effect on students' mathematics performance. Meanwhile, the heterogeneity analysis was significant ($Q= 361.961$, $df = 22$, $p<0.001$), and the calculated effect sizes vary between 0.994 (lower limit) to 1.722 (upper limit) at a 95% confidence interval based on the random effect model. This reveals that the studies included in the meta-analysis do not have a common effect size. Hence, the distribution of effect sizes among the studies was significantly heterogeneous, and some factors other than sampling error accounted for the variance. Furthermore, a I^2 value of 93.92 suggests that the moderator or subgroup analysis is valuable (Borrenstein et al., 2014). Moreover, Table 3 presents the detailed distribution of the effect sizes among the included studies.

Table 3
Distribution of the effect sizes among the included studies

Study Name	Hedges's g	Standard Error	Variance	95% CI Lower Limit	Upper Limit	Z-value	P-value
Abari & Tyovenda (2021)	0.517	0.184	0.034	0.155	0.878	2.801	0.005
Ahdhianto et al (2020)	1.047	0.149	0.022	0.755	1.339	7.034	0.000
Al Tamimi (2017)	3.297	0.299	0.084	2.729	3.884	11.392	0.000
Alzharani (2022)	2.194	0.314	0.099	1.579	2.810	6.967	0.000
Aminah et al. (2018)	0.252	0.237	0.056	-0.213	0.718	1.062	0.288
Casaig (2019)	2.198	0.406	0.164	1.403	2.993	5.420	0.000
Dagoc & Tan (2018)	0.101	0.300	0.090	-0.486	0.688	0.338	0.736
Gaylo & Dales (2017)	0.888	0.267	0.072	0.364	1.412	3.319	0.001
Hasan et al (2019)	0.149	0.271	0.073	-0.383	0.680	0.548	0.584
Lestari & Jailani (2018)	0.519	0.257	0.066	0.014	1.023	2.014	0.044
Lotfali & Alem (2017)	2.887	0.401	0.161	2.101	3.673	7.199	0.000
Miller & William (2019)	0.472	0.208	0.043	0.064	0.879	2.268	0.023
Okpanachi & Umoru (2021)	1.472	0.264	0.069	0.956	1.989	5.586	0.000
Ozcan & Erktin (2015)	0.235	0.345	0.119	-0.441	0.911	0.682	0.495
Prabawanto (2017)	1.155	0.198	0.039	0.768	1.543	5.840	0.000
Rizk et al. (2017)	2.786	0.439	0.190	1.925	3.647	6.340	0.000
Saeedullah & Akbar (2021)	7.271	0.654	0.427	5.909	8.552	11.120	0.000
Syaiful et al. (2022)	1.700	0.255	0.065	1.200	2.200	6.665	0.000
Iqbal et al. (2017)	0.473	0.225	0.050	0.033	0.913	2.106	0.035
Osuafor & Obimezie (2021)	1.644	0.188	0.035	1.275	2.013	8.727	0.000
Shilo & Kramarski (2019)	0.392	0.070	0.005	0.254	0.530	5.580	0.000
Tzohar-Rozen et al. (2017)	0.669	0.190	0.036	0.296	1.042	3.517	0.000
Fauzi (2018)	1.428	0.266	0.082	0.867	1.989	4.988	0.000

Upon analyzing the individual study in included in this meta-analysis presented in Table 3, it was found that Saeedullah and Akbar (2021)(g=7.271); al Tamimi (2017) (g=3.279); Lotfali and Ghanbarpour Alem (2017) (g=2.887); Rizk et al. (2017) (g=2.786); Casaig (2019) (g=2.198); Alzahrani (2022) (g=2.194); Syaiful et al. (2022)

(g=1.700); Osuafor and Obimezie (2021) (g=1.644); Okpanachi and Umoru (2021) (g=1.472); Fauzi (2018) (g=1.428); Prabawanto (2018) (g=1.155); Ahdhianto et al. (2020) (g=1.047) and Gaylo and Dales (2017) (g=0.888) obtained a large and positive effect sizes. The study of Tzohar-Rozen and Kramarski (2017) (g=0.669); Lestari & Jailani (2018) (g=0.519); Abari and Tyovenda (2021) (g=0.517) obtained a medium and positive effect sizes. The study of Iqbal et al. (2017) (g=0.473); Miller and William (2019) (g=0.427); Shilo and Kramarski (2019) (g=0.329); Aminah et al. (2018) (g=0.252); Özcan and Erktin (2015) (g=0.235) had small effect size. However, Hasan et al. (2019) (g=0.149); Dagoc and Tan (2018) (g=0.101) had no effect sizes.

In order to verify the obtained effect of MBPI, publication bias was investigated using funnel plot analysis. Through visual inspection, it illustrates 13 outliers out of 23 studies which shows asymmetry. However, funnel plot asymmetry is not always a reliable measure of publication bias since funnel plot asymmetry has several potential explanations and a variety of other underlying causes (Sterne et al., 2011). Furthermore, the “Duval and Tweedie’s trim and fill” method was utilized to provide symmetry corrections as presented in Table 4 and in Figure 3.

Table 4
Duval and Tweedie’s trim and fill

		Fixed Effects			Random Effects			
	Studies Trimmed	Point Estimate	Lower Limit	Upper Limit	Point Estimate	Lower Limit	Upper Limit	Q Value
Observed Values		0.84531	0.76234	0.92829	1.37328	1.00531	1.74124	363.18953
Adjusted Values	6	0.67091	0.59446	0.75466	0.73871	0.32021	1.15721	656.00584

As shown in Table 5, the adjusted values obtained six studies trimmed which must be imputed. Furthermore, as seen in Figure 3, the symmetry has been formed by adding the six (6) imputed studies on the left side indicated in black dots due to the correction. This method corrects the effect caused by publication bias based on the fixed effects model, resulting in an adjusted effect value (g=0.67091), indicating a medium effect size. In contrast, the random effect model adjustment suggested zero studies to impute. To confirm these findings, the Begg-Mazumdar rank correlation yields a p-value of 0.34387 (p=0.02518), indicating a publication bias among the examined studies. The consistent publication bias results are sufficient evidence of effect size inflation. The six studies are missing to have a definitive idea of the calculated fixed and random effects, which might be updated in the future meta-analysis. Further analysis was done using the Classic fail N test, which revealed the meta-analysis of the 23 studies is valid (p<0.001), and 3216 studies would be required to nullify the overall effect size.

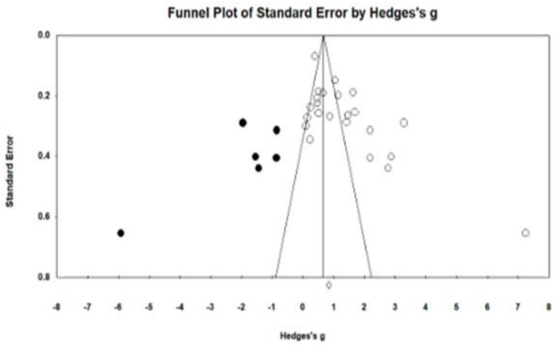

Figure 3
Trim and fill method

Moderator Analysis

To determine the significant differences of the effect size between groups, a moderator analysis was conducted as presented in Table 5.

Table 5
Moderator analysis

Study Group	k	ES (g)	SE	Variance	95%CI		z	p	Heterogeneity		
					Lower	Upper			Q	df	P_Q
Education level	23	1.189	0.170	0.029	0.856	1.521	7.009	0.000	4.009	2	0.135
Primary	7	0.891	0.228	0.052	0.444	1.338	3.910	0.000			
Secondary	11	1.666	0.359	0.129	0.962	2.370	4.639	0.000			
Tertiary	5	1.452	0.359	0.129	0.748	2.156	4.041	0.000			
Subject Area	23	0.916	0.089	0.008	0.072	1.091	10.310	0.000	94.923	5	0.000
Algebra	3	1.919	0.609	0.371	0.726	3.113	3.152	0.002			
Arithmetic	3	2.572	0.746	0.557	1.110	4.034	3.448	0.001			
Geometry	4	0.445	0.113	0.013	0.224	0.666	3.950	0.000			
Math Word Problems	6	0.884	0.202	0.041	0.487	1.280	4.370	0.000			
Statistics and Probability	1	3.297	0.289	0.084	2.729	3.864	11.392	0.000			
Not specified	6	1.468	0.380	0.144	0.723	2.213	3.863	0.000			
Targeted learning Outcomes	23	1.041	0.148	0.022	0.725	1.303	6.870	0.000	8.355	5	0.138
Conceptual Understanding	9	1.134	0.268	0.072	0.609	1.659	4.235	0.000			
Mathematical Communication	2	2.158	1.125	1.265	-0.047	4.363	1.919	0.055			
Logical Thinking Ability	2	0.824	0.588	0.345	-0.323	1.981	1.411	0.158			
Problem Solving Skills	6	0.759	0.201	0.040	0.365	1.153	3.777	0.000			
Reasoning Ability	2	3.868	3.376	11.397	-2.749	10.485	1.146	0.252			
Creative Thinking Ability	2	2.184	0.540	0.291	1.126	3.242	4.045	0.000			

It was revealed that the implementation of MBPI in terms of different educational levels had a large effect on the secondary level (g=1.666) and tertiary levels (g=1.452), followed by the primary level (g=0.891). Further heterogeneity tests showed no significant differences among the effect sizes of the included studies (Q=4.009, df=2, p=0.135), indicating that they share common effect sizes. In terms of the implementation of MBPI in different subject areas, it was found that statistics and probability (g=3.297), arithmetic (g=2.572), and algebra (1.919) had a large effect. In contrast, geometry (g=0.445) had a small effect. The heterogeneity results in the subject areas are significant (Q=94.923, df=5, p<0.001), which suggests the differences in the effect sizes of the math subdomain. As regards the targeted learning outcomes, MBPI had a large effect on mathematical reasoning ability (g=3.868), creative thinking ability (g=2.184), mathematical communication (g=2.158), conceptual understanding (g=1.134), logical thinking ability (g=0.824), and mathematical problem-solving skills (g=0.759) had a medium effect. Further heterogeneity test showed no significant differences (Q= 8.355, df=5, p=0.138). These results suggest the effect of MBPI on students' mathematics performance does not differ concerning the targeted learning outcomes.

Metacognitive-based Pedagogical Intervention

This meta-analysis determined the specific metacognitive strategies employed in the individual studies. It was found that 69.57 % of the study used the metacognitive strategy (e.g., planning, monitoring, evaluation, think-aloud, journal writing, concept mapping, KWL), followed by the IMPROVE metacognitive strategy (13.04%) and metacognitive questions and metacognitive scaffolding (8.70%). Further, moderator analysis concerning the specific MBPI used was also analyzed. Findings revealed that the metacognitive strategy (e.g., planning, monitoring, evaluation, think-aloud, journal writing, concept mapping, KWL) (g=1.611), IMPROVE (g=0.998), metacognitive questions (g=0.874) had a large effect. In contrast, the metacognitive scaffolding (g=0.652) has a medium effect. Further heterogeneity test showed no significant difference (Q=3.839, df =3, p=0.279), which indicates that the intervention's effect size does not vary.

DISCUSSION

This meta-analysis aimed to determine the effectiveness of the metacognitive-based pedagogical intervention (MBPI) on students' mathematics achievement**.** Twenty-three (23) empirical studies from 2015 to 2022 were analyzed with 2616 students from various education levels. The random and fixed effect models showed significant effects in favor of the metacognitive-based pedagogical intervention. Random-effect models was used since generalization of these results is regarded as very stable and reliable because 2616 participants were involved in the meta-analysis. Random-effects models are appropriate when the number of studies is sufficient; that is, when there are enough studies to support generalizations beyond the included studies (Tafanaru et al., 2015). The effectiveness of metacognitive strategies-based instruction can be attributed to its benefits on students' ability to understand and control their cognitive processes (Ingole & Pandya, 2016). Since mathematics is considered an abstract science, applying active learning and ensuring that metacognitive abilities can be developed are essential to make teaching and learning practices more focused and relevant (Abu Bakar & Ismail, 2020). Thus, it is suggested that educators consider teaching embedded with metacognitive strategies, especially in mathematics subjects. Based on the heterogeneity test results (Q=361.961, p<0.001), the studies' influence quantities have varied effect sizes. The I^2 statistics (I^2 = 93.922) also demonstrate a high-level indicator of heterogeneity; hence, the moderator analysis is possible. The moderator analysis was conducted in terms of the education level of the samples, the subject area, and the targeted learning outcomes.

When the implementation of MBPI was examined in terms of different educational levels, it revealed that it had a large effect on the secondary level (g=1.666) compared to the tertiary level (g=1.452) and primary level (g=0.891). Further heterogeneity test indicates that the impact of MBPI on students' mathematics performance does not differ concerning educational level. Thus, the educational level is not included in the factors that may affect the students' mathematics performance using MBPI, and it can be effectively utilized across various educational levels. This can be explained since the metacognitive capacity of a learner begins in their earlier development, and it is more conducive to instructional intervention and can be taught to a variety of learners (Pedone, 2014). Also, the learning performance of a learner impacted by metacognition has its developmental phase, and not all metacognitive skillfulness develops at the same time or rate (Stel, 2011). Thus, educators must encourage the appropriate metacognitive strategy used in the proper stage of growth and phase of students.

In relation to the implementation of MBPI in different subject areas, it was found that statistics and probability had the largest effect (g=3.297). The heterogeneity test also shows a significant difference in students' mathematics performance. Al Tamimi (2017) implemented a metacognitive strategy (K.W.L.) in teaching statistics and probability, emphasizing the learning process of identifying prior knowledge, learning-related knowledge, and acquired knowledge in statistics and probability. The large effect can be explained since statistics and probability subjects focus on data analysis and probability theory to help students learn how to draw conclusion and making predictions. And it is noted that metacognitive strategy often associated with making decisions based on gathered data and being able to solve problems (Rysz, 2004). Moreover, arithmetic (g=2.572) and algebra (1.919) obtained large and positive effect sizes, while geometry (g=0.445) had a small effect. These findings show that different subject areas affect students' mathematics performance. Therefore, educators should consider various math subdomains especially in statistics and probability while implementing metacognitive-based pedagogical instruction to improve students' mathematics performance.

With regards to the effectiveness of MBPI in improving mathematics performance in terms of the targeted learning outcomes, a large effect was found on mathematical reasoning ability (g=3.868), creative thinking ability (g=2.184), mathematical communication (g=2.158), conceptual understanding (g=1.134 logical thinking ability (g=0.824), and problem-solving skills (g=0.759) had a medium effect. Further heterogeneity test showed no significant differences. This implies that the impact of MBPI on students' mathematics performance does not differ and is not considered as the factor that may affect the students' mathematics performance using metacognitive pedagogical instruction. Saeedullahand Akbar (2021) was seen in the study with a large effect on students' mathematical reasoning ability, utilizing metacognitive techniques in collaborative settings as the intervention's delivery methods. The intervention gave the students the chance to learn and communicate with one another. As a result, the metacognitive intervention helped them control their thought processes, and they were able to apply mathematical concepts correctly and logically. Meanwhile, Lestari and Jailani (2018), who investigated collaborative learning embedded with metacognitive strategies, garnered a medium effect size. It was observed that both of the studies were integrated and effective in a collaborative learning setup. The utilization of student-led collaborative learning was not always effective, and it frequently achieved desirable learning objectives. However, metacognitive intervention encourages student groups to actively learn from one another (Khosa & Volet, 2013). Involving group members in cooperative tasks necessitates shared understanding and cognitive, metacognitive, and social insight and expertise to form a suitable team or to work together and take concerted action to address the issue (OECD, 2013). Thus, MBPI can be used effectively in improving different students' learning outcomes in mathematics education.

The present study analyzes the different metacognitive-based pedagogical interventions, and the majority of the study utilized various metacognitive strategy techniques (e.g., planning, monitoring, evaluation, think-aloud, journal writing, concept mapping, KWL). Follow-up analysis showed that the metacognitive strategy (e.g., planning, monitoring, evaluation, think-aloud, journal writing, concept mapping, KWL) (g=1.611) had a large effect on mathematics achievement. It has been observed that metacognitive strategies assist in identifying students' thought processes which help them become conscious of their learning capacities. According to Chatzipanteli et al. (2014), students who apply their metacognitive skills can better identify problems, and determine how to reinforce what they have learned. As a result, metacognition supports student success. Further moderator analysis revealed that the intervention's effect size does not vary. The metacognitive strategy, IMPROVE, metacognitive questions, and metacognitive scaffolding do not differ in improving students' mathematics performance. This reveals that different metacognitive-based pedagogical strategies were all effective and can be efficiently utilized.

CONCLUSION AND RECOMMENDATIONS

A total of 23 empirical studies from 2015 to 2022 were included in the meta-analysis on the effectiveness of the metacognitive-based pedagogical intervention (MBPI) on students' mathematics achievement.

As revealed in this study, a significantly large and positive effect was found, indicating that using MBPI can indeed enhance students' mathematics achievement. Further moderator analysis shows significant differences when grouped according to mathematics subject area in the effect sizes of each study. Meanwhile, in terms of the educational level, targeted learning outcomes, and the specific metacognitive pedagogy used found no significant differences. It implies that MBPI can be utilized effectively in a wide range of samples since the level of education does not vary. The study also explores the different metacognitive-based interventions, and the majority used strategies and techniques such as planning, monitoring, evaluation, think-aloud, journal writing, concept mapping, and KWL. It was found that different metacognitive-based interventions can impact and effectively enhance students' mathematics achievement. Since metacognitive strategy focuses on helping students control and manage their own learning, it will help students achieve better mathematics performance. Its effectiveness was evident in this meta-analysis. Thus, teachers should implement and continuously incorporate metacognition in their teaching practices. Moreover, implementing metacognitive strategies is crucial, and teachers must be provided with proper training and encouragement. This research offers relevant findings beneficial to both students and administrators, which serve as a foundation for making decisions about introducing a potential intervention that impacts mathematics education. In this regard, the integration and utilization of metacognitive strategy should be further investigated by future researchers so that a more comprehensive approach can be empirically explored.

LIMITATIONS

A few variables may have contributed to the publication bias found in the study. Note that the number of studies included in the meta-analysis is limited (n<100), and the decision of researchers to identify particular studies based on inclusion and exclusion criteria may be prone to selection bias. According to Ahmed et al. (2012), publication bias may have occurred due to data availability bias and reviewer selection bias. Highlighting the trim and fill method, six studies missing were needed, which might be updated for future study. Also, the findings of this research are restricted to only the eligible studies in this meta-analysis. As a result, they might not be an accurate indicator of the total effect size. Furthermore, the study only focused on mathematical achievement and did not look at different outcomes, such as the emotional impact, and should investigate other variables, including individual factors, to better understand how to utilize metacognitive instruction. Lastly, since the investigated subgrouping was also constrained by the studies that fulfilled the inclusion criteria, this paper serves as an initial attempt to inform educators regarding the potential effects of implementing the metacognitive-based pedagogical intervention.

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