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Meta-Analysis Study: Effect of Means Ends Analysis (MEA) Model on Student's Mathematical Problem-Solving Skills

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Abstrak

Tinjauan komprehensif dampak Means Ends Analysis (MEA) terhadap keterampilan pemecahan masalah matematika belum dipelajari secara ekstensif, Akibatnya, hanya sedikit guru yang menyadari manfaat pendekatan ini bagi anak-anak. Studi meta-analisis ini dilakukan untuk menilai dampak keseluruhan dari pengajaran siswa untuk memecahkan masalah matematika dengan menggunakan pendekatan MEA. Informasi empiris diperoleh dari tautan URL, Semantic Scholar, dan Google Scholar. Pencarian menghasilkan 18 artikel yang ditulis antara tahun 2009 dan 2023. 18 item memenuhi syarat untuk dianalisis karena memenuhi kriteria inklusi. Dalam alat analisis, model estimasi acak dan perangkat lunak Comprehensive Meta-Analysis (CMA) keduanya digunakan. Hasil penelitian menunjukkan bahwa ukuran efek keseluruhan dari penelitian ini adalah 0,920. Hasil tersebut menunjukkan bahwa penggunaan MEA memiliki pengaruh yang signifikan terhadap kemampuan pemecahan masalah matematis siswa. Setelah memeriksa variabel moderator, ditemukan bahwa model MEA berhasil ketika mempertimbangkan jumlah sampel siswa, tetapi tidak ketika mempertimbangkan tingkat pendidikan dan demografi siswa. Penerapan MEA dalam meningkatkan kemampuan pemecahan masalah matematis siswa sebaiknya lebih sering diterapkan, khususnya di sekolah dasar, menurut saran studi metaanalisis ini kepada guru matematika Indonesia.

Kata Kunci: Analisis Sarana Berakhir, Pemecahan Masalah Matematika, Studi Meta-analisis, Variabel Moderator

Abstract

A comprehensive review of Means Ends Analysis (MEA) impact on mathematical problem-solving skills has not been studied extensively, As a result, few teachers are aware of the benefits that this approach has for children. This meta-analysis study was conducted to assess the overall impact of teaching students to solve mathematical problems using the MEA approach. Empirical information was obtained from URL links, Semantic Scholar, and Google Scholar. The search produced 18 articles that were written between 2009 and 2023. 18 items were eligible for analysis because they met the inclusion criteria. In the analysis tool, a random estimation model and Comprehensive Meta-Analysis (CMA) software are both utilized. The outcomes showed that the overall effect size of the study was 0.920. These results imply that the use of the MEA has a significant impact on students' mathematical problem-solving skills. After examining the moderator variables, it was found that the MEA model was successful when considering student sample sizes, but not when considering the educational level and demographics of the students. The application of MEA in enhancing students' mathematical problem-solving should be employed more frequently, particularly in elementary schools, according to this meta-analysis study's advice to Indonesian math teachers.

Keywords*: Means Ends Analysis, Mathematical Problem Solving, Meta-analysis study, Moderator Variables*

Introduction

According to the NCTM (National Council of Mathematics Teachers), one of the standard abilities that students must know is mathematical problem-solving (NCTM, 2014). A crucial skill that students must apply and develop is problem-solving (Miranti et al., 2015). In other literature, it is revealed that for students involved in mathematical problem-solving, it will provide a strong foundation for understanding mathematical ideas and materials (Faoziyah, 2022). Mathematical material will be readily understood through problem-solving skills and problem-solving skills can be trained through learning mathematics (Syahrul & Musdi, 2019). Therefore, teachers need to pay attention to students' problem-solving abilities when instructing and learning math. Mathematical skills include conceptual comprehension, procedural fluency, and adaptable reasoning that must be developed when students are learning mathematics in addition to strategic competence or problem-solving and productive disposition (Kilpatrick et al., 2001). The stages of problem solving are as follows: (1) comprehending the problem, which requires recognizing the aspects that are already known, the elements that are being requested, and deciding whether the elements are enough to solve the issue; (2) combining the parts that are known and those that are being requested, then organizing them into a mathematical model of the issue; (3) deciding on a solution approach, providing details, and performing computations; or (4) finishing mathematical models; and (4) analyzing the outcomes (Ita & Abadi, 2019).

Scientists who work with mathematics educators chose the Means Ends Analysis (MEA) method as one alternative for developing and improving still-weak solving mathematical puzzles skills. The MEA approach was chosen as one solution because it makes students more active in learning, students can too analyze or complete their problem-solving, as well as the usefulness of mathematics in general to humans, so that students are more motivated (Supendi et al., 2017). As a result, many schools use the Means Ends Analysis (MEA) paradigm to teach mathematics at all levels of formal education to develop and improve students' capacity for solving mathematical skills.

Until now, researchers in Indonesia and other countries have extensively examined the capacity for mathematical problem-solving using the MEA method. However, according to multiple studies reported in various journals, the Means Ends Analysis (MEA) method significantly improves pupils' capacity for addressing mathematical problems (Asih & Ramdhani, 2019; Nurhanifah, 2018; Wibowo et al., 2016; Yudha et al., 2019). Other researchers, on the other hand, contend that Means Ends Analysis (MEA) has no substantial influence on students' mathematical problem-solving ability (Sari & Masri, 2020). Inconsistent findings from this research give ambiguous and erroneous information regarding the impact of the MEA technique on pupils' capacity to solve mathematical problems. On the other hand, policymakers in the field of education, particularly mathematics teachers, require precise and accurate information such as: at what level of education, what sample size, and where student demographics, This influences the variation in effect size of the MEA method on the aptitude of students to resolve issues.

Based on this, it is necessary to organize data from several articles found and reviewed to obtain as much information as possible, especially how much effect using meta-analysis, the Means Ends Analysis (MEA) technique has an impact on Problem-solving abilities. Meta-analysis is an overall and empirical review of quantitative studies by summarizing effect sizes based on measures of central tendency and evaluating representations of research error or bias (Siddaway et al., 2019). The effect size is an index that measures the relationship between two variables or the difference between two groups (Borenstein, 2009).

No meta-analysis study examines specifically how the MEA model is applied. However, there have been several meta-analytic studies related to improving problem-solving abilities using PBL, Discovery Learning, RME, and other learning approaches. Research Yustinaningrum (2021) based on study findings, with a fairly large category and an average effect size of 2.02. And It can be inferred from the results of the paired sample t-test and the average impact size that the problem-based learning approach affects students' capacity for solving mathematical problems. Similar research was conducted by Saputri & Wardani (2021) according to the study's findings, problem-solving and problem-based learning models had significantly different effects on students' ability to solve mathematical problems at the primary school level. As a result, researchers are eager to investigate the impact of MEA on mathematical problem-solving abilities from 2009 to 2023, as well as features such as student demographics, sample size, and educational level, using Comprehensive Meta-Analysis Software (CMA).

This study intends to explain, quantify, and evaluate the impact of implementing MEA on improving students' ability to solve mathematical problems across Indonesia as well as to pinpoint research features that have an impact on different effect size data. The extensive information on the impact of MEA provided by this study on Indonesian students' problem-solving abilities. To teach and develop students' thinking skills, it may be thought that educators should implement an ideal learning process.

Methodology

The approach in use for this inquiry is meta-analysis. This is due to the research's use of a quantitative approach to synthesize multiple pertinent primary studies. The meta-analysis study goes through various stages. The benefits of this approach include increased transparency, rigorous methodology, greater population parameter prediction, analysis of results across many domains, detection, and reduction of bias, and significantly strong evidence (Litte et al., 2008; Litte et al., 2008). The meta-analysis approach, according to (Borenstein et al., 2009) involves multiple stages, which are depicted in the flow chart in Figure 1 below.

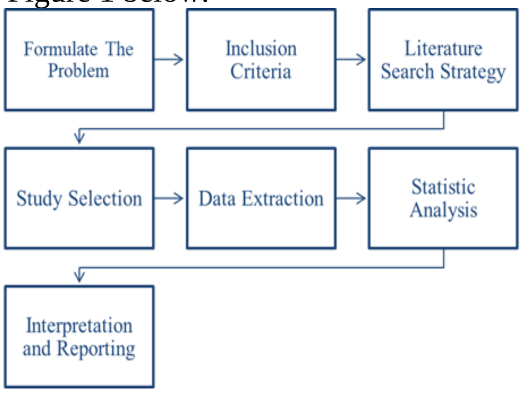

Figure 1. Diagram illustrating the steps in the meta-analysis process

Therefore, these steps will be used in this investigation. In this section, the researcher will outline several procedures, such as the selection of studies, statistical analysis, data extraction, and search strategies for the literature.

Inclusion Criteria

The impact of the MEA model on students' ability to solve mathematical problems is yet the subject of a general and thorough preliminary study. Based on the PICOS (Population, Interventions, Comparator, Outcomes, and Study Design) approach (Liberati et al., 2009), To limit the scope of the meta-analysis, the following inclusion criteria were established:

1. Indonesian students make up the primary study population.
2. The MEA Model's implementation was the preliminary study's intervention.
3. The application of traditional learning is the comparison of the intervention in the earlier research.

4. The core study's output is the ability of the students to solve mathematical problems.
5. The preceding study used causal-comparative quasi-experimental research as its research design.
6. The mean, standard deviation, sample size, t-value, and p-value for the experimental and control groups were the main statistical information provided.
7. Between 2009 and 2023, primary investigations are published in journals or proceedings.

The meta-analysis omitted primary studies that didn't fit the inclusion criteria.

Literature Search Strategy

Google Scholar, Semantic Scholar, and URL links from publications were utilized to search the electronic database for literature on applying the MEA model to students' mathematical problem-solving abilities. In the literature search, the terms "MEA Model" and "Mathematical problem-solving skill" were used. Some primary research that meets the inclusion requirements can be located and found with the assistance of databases and keywords.

Study Selection

The primary study was chosen based on inclusion criteria. According to the PRISMA protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analysis), the study selection procedure was divided into four steps: identification, screening, eligibility, and inclusion (Liberati et al., 2009).

Extracting Data

The author's name, statistical information (mean, standard deviation, sample size, t-value, and p-value), and the year of publication were processed by the researcher, following the inclusion criteria and study selection phases, to assess its validity and plausibility. Results from a meta-analytical study will be of high quality if the data are reliable and valid.

Statistical Analysis

The Hedge g algorithm was used to determine the effect size value for this meta-analysis (Borenstein, 2009). This is due to the experimental class's (MEA Class's) small sample size (Harwell, 2020). Table 1 displays the categorization of effects according to Thalheimer & Cook (2002).

Table 1. Effect Size Classification in Thalheimer & Cook's Study

Effect Size (ES)	Interpretation
$-0,15 \leq ES < 0,15$	Ignored
$0,15 \leq ES < 0,40$	Low
$0,40 \leq ES < 0,75$	Medium
$0,75 \leq ES < 1,10$	High
$1,10 \leq ES < 1,45$	Very High
$1,45 \leq ES$	Excellent

Analysis of publication bias and sensitivity is essential to assure the accuracy of the statistical information in every major study because publication bias will always affect the results (Bernard et al., 2014; Doi & Furuya-Kanamori, 2020). Utilizing funnel plots, fill and trim tests, and the Rosenthal fail-safe N test, publication bias analysis was conducted (Harwell, 2020). Regarding the sensitivity analysis performed using the CMA software's "One Study Removed" tool (Bernard et al., 2014).

The fixed effect model and the random effect model are the two types of effects employed in the meta-analysis investigation (Borenstein, 2009; Cheung, 2015). The p-value of the Cochran-Q statistic can be used to identify the effect model chosen for the meta-analysis procedure and the variation in effect size data (Borenstein, 2009; Siddiq & Scherer, 2019).

Findings and Discussions

According to established inclusion criteria, eighteen articles were used in this investigation.

Table 2. MEA Article Data on Mathematical Problem Solving Ability

Code	Citation	Statistical Data						t-value
		MEA Class			Conventional Class			
		N	Mean	SD	N	Mean	SD	
PM	Syahrul & Musdi, 2019	36	61.81	17.46	35	53.49	19.21	

01								
PM02	Supendi et al., 2017	37	64	18.86	38	57	11.42	
PM03	Yudha et al., 2019	32	83.28	9.2	32	62.11	16.7	
PM04	Nurhanifah, 2018	35	83.09	16.72	35	83.65	10.85	
PM05	Wibowo et al., 2016	32	70.69	12.47	32	64.75	10.75	
PM06	Asih & Ramdhani, 2019	32	34	5.534	30	4.57	1.501	
PM07	Noviyanti et al., 2021	31	77.484	14.54	34	69.059	18.85	
PM08	Palupi et al., 2016	36	80.111	13.654	35	60.229	15.462	
PM09	Jais & Faizal, 2019	22	80.9	10.07	22	75	8.99	
PM10	Silvi, 2021	17	82.35	9.924	17	81.59	10.038	
PM11	Hidayati et al., 2023	16	84.375	11.2361	16	72.812	15.8607	
PM12	Sari & Masri, 2020	30	23.4	3.785	30	21.1	3.832	
PM13	Permana, 2023	40	49.21	8.42	40	46.6	6.52	
PM14	Wulandari et al., 2021	35	87.07	5.565	35	78.75	7.395	
PM15	Solikah & Himmah, 2019	25			25			0.005
PM16	Juanda et al., 2014	31			31			9.636
PM17	Imaniah & Nurjanah, 2018	35			34			0.005
PM18	Karolina et al., 2021	32			32			3.61

According to Table 2, eighteen articles use the MEA technique as the experimental class in their quasi-experimental research, which is of the causal-comparative type. The main objective of this study was to measure the overall effect of MEA training on students' Problem-solving abilities. How much of an impact a treatment has is determined by the size of the effect. A meta-analysis of how the MEA approach influences students' ability to solve mathematical problems serves as the link between factors in this case. Seventeen of the eighteen articles have a significant impact, while one has a moderate impact. Table 3 presents the research's findings.

Table 3. Article Effect Size Data

Citation	Effect Size	Variance	Confidence Interval	
			Lower Limit	Upper Limit
Syahrul & Musdi, 2019	0.955	0.047	0.531	1.380
Supendi et al., 2017	0.956	0.047	0.531	1.381
Yudha et al., 2019	0.882	0.044	0.473	1.291
Nurhanifah, 2018	0.981	0.044	0.567	1.394
Wibowo et al., 2016	0.951	0.047	0.528	1.375
Asih & Ramdhani, 2019	0.678	0.021	0.395	0.961
Noviyanti et al., 2021	0.952	0.047	0.528	1.376
Palupi et al., 2016	0.896	0.045	0.481	1.311
Jais & Faizal, 2019	0.943	0.046	0.523	1.363
Silvi, 2021	0.970	0.045	0.556	1.384
Hidayati et al., 2023	0.929	0.045	0.512	1.345
Sari & Masri, 2020	0.945	0.047	0.522	1.369
Permana, 2023	0.962	0.047	0.537	1.387
Wulandari et al., 2021	0.903	0.045	0.486	1.320
Solikah & Himmah, 2019	0.977	0.045	0.563	1.391
Juanda et al., 2014	0.822	0.038	0.440	1.204
Imaniah & Nurjanah, 2018	0.979	0.045	0.564	1.393
Karolina et al., 2021	0.927	0.047	0.505	1.350

Based on Table 3, different effect sizes, with a 95% confidence level, are 0.678 to 0.981. The results of the study demonstrate that the MEA strategy has a positive impact on pupils' ability to solve mathematical problems. Additionally, as stated in Table 4 below, The fixed effect model and the random effect model will be used to present the results of the meta-analysis of the primary investigations.

Table 4. Description of the Results of the Meta-analysis according to the Estimation Model

Estimation Model	n	Z	P	Effect Size	Standard Error	95% CL		Qb	P-Value	I-Squared
						Lower Li	Upper Li			

						mit	mit			
Fixed Model	18	10.706	0.000	0.684	0.064	0.559	0.809	168.95	0.000	89.938
Random Model	18	4.529	0.000	0.920	0.203	0.522	1.318			

The outcomes of the meta-analysis are contrasted in Table 4 based on the effects model. Table 4 shows that, according to the fixed effects model, the 95% confidence interval's lower and upper bounds, respectively, are 0.559 and 0.809, respectively. The overall effect size of the study was 0.684. This effect size is recognized as being moderate. The random effect's 95% confidence interval has a lower limit of 0.522 and an upper limit of 1.318. The overall effect size of the study was 0.920. This effect size is acknowledged as being high. Testing for heterogeneity and selecting an estimating model comes next. According to Table 4, Qb is valued at 168.95, while p is valued at 0.000. The actual impact size varied from study to study; as a result, the distribution of effect size was diverse at $p < 0.05$. Given that the p-value is less than 0.05, it can be deduced that, as compared to traditional learning, the means-ends analysis learning strategy significantly influences students' ability to solve problems. The I-squared score of 89.938, which denotes that 89.938% of the variance in The extent of the observed effect indicates the proportion of variability brought on by actual heterogeneity (not due to sampling error), reflects the degree of effect size variation between studies. Because of the significant heterogeneity of this study and its I-squared score of 89%. A random-effect model was selected as the estimated model because the homogeneity test results were disregarded. The research shown in Figure 2's funnel plot is shown below.

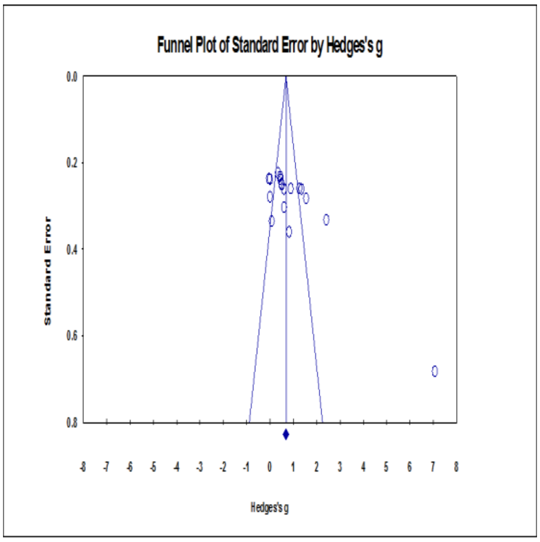

Figure 2. Funnel Plot Check for Publication Bias

Figure 2 demonstrates that the effect size distribution is symmetrical around the vertical line. Also looked at was Rosenthal's Fail-Safe N (FSN) statistic. The N number was determined to be 702 by CMA calculations. The result of the calculation of 702 / ((5 x 18) + 10), was 7,02 > 1. The research used in this analysis is not biased by publication. Therefore, due to publication bias, no studies were lost or needed to be added to the analysis.

To test the study hypothesis, the p-value must be calculated as the final step. The analysis's findings are contrasted in Table 4 based on the estimating model. The random effect model's 95% confidence interval, shown in Table 4, runs from 0.522 to 1.318, indicating that the mean difference may fall anywhere within this range, while the study's overall effect size is 0.920. As a strong effect, this effect size is acceptable. The Z test was used to calculate statistical significance, and the z score came out to be 4.529. At the threshold of $p < 0.001$, this result might be deemed statistically significant. As a result, using means-ends analysis has a bigger impact on students' problem-solving abilities than using traditional learning models. The next stage is to examine the impact of moderator variables on nine effect sizes from nine primary studies, including education level, sample size, and student demographics. The

CMA was used to determine Hedges-g values, 95% confidence intervals, Z, and p. Table 5 lists the meta-analysis findings for the following study characteristics.

Table 5. The Meta-Analysis's Findings and Each Study's Characteristics

Moderator Variable	Group	n	Effect Size	Test of Null (2-Tail)		Heterogeneity		
				Z	P	Between Effect Class (Qb)	Df (Q)	P
Education Level	Elementary School	1	1.271	4.851	0.000	6.280	2	0.043
	Junior High School	14	0.630	8.877	0.000			
	Senior High School	3	0.842	4.446	0.000			
Sample Size	<= 30	5	0.414	3.017	0.003	5.329	1	0.021
	> 30	13	0.772	10.585	0.000			
Student Demographics	City	8	0.733	7.970	0.000	0.366	1	0.545
	Regency	10	0.655	7.258	0.000			

Based on Table 5, it was discovered that the research conducted at the elementary school level (1.271) had a stronger impact than middle school in terms of size (0.630) and high school (0.842) for the moderating variable of education level. An elementary school has a very high effect size, middle school has a moderate effect size, and high school has a high effect size. The findings of the heterogeneity test indicated that there was no difference in the average impact size between educational levels ($Q = 6.280$ and $p > 0.05$). It can be concluded that the use of the mean ends analysis approach to enhance students' problem-solving abilities is unaffected by students' educational background because the distribution of effect sizes for the three categories of the study characteristics is homogeneous and the p-value for this analysis is greater than 0.05. The MEA strategy is successful at the elementary school level, according to research (Wulandari et al., 2021) that looks at the impact of MEA on pupils' problem-solving abilities.

It was discovered that, for the sample size variable, studies with less than or equal to 30 samples (0.414) had a smaller significant effect size than those with more than 30 samples (0.772). A high effect size is defined as more than 30 samples, while a moderate effect size is defined as fewer than or equal to 30 samples. The average impact size between educational levels was varied, according to the results of the heterogeneity test ($Q = 5.329$ and $p < 0.05$); because of the diverse distribution of effect sizes for both categories on the parameters of the sample size study. As a result, there is a significant difference between the effects of applying the Means Ends Analysis Model on students' mathematical problem-solving abilities based on sample sizes, leading to the conclusion that the sample sizes that were used have an impact on the application of the Means Ends Analysis Model to improve students' mathematical problem-solving abilities. According to studies by Siddiq & Scherer, 2019 and Tamur et al., 2020, the sample sizes' features of students had a substantial impact on the effect sizes' heterogeneity. It is conceivable that the application of MEA would be most effective in improving students' problem-solving abilities, particularly in classes with more than thirty pupils. It was discovered that research from the city (0.733) had a more significant effect size than that from the regency (0.655) for the student demographic moderator variable. The city and regency's effect size is categorized as medium. The findings of the heterogeneity test indicated that there was no difference in the average impact size between the student demographics ($Q = 0.366$ and $p > 0.05$); since the p-value > 0.05, On the characteristics of the student demographic research, the distribution of impact sizes for both categories is uniform. Since there is no discernible difference in how applying the mean ends analysis approach affects students' ability to solve mathematical problems based on student demographics, it can be said that this approach's application to enhance students' problem-solving abilities is unaffected by student demographics. Contrary to other studies Siddiq & Scherer, (2019) and Tamur et al., (2020), this finding demonstrated how the demographic makeup of students greatly influenced the heterogeneity of impact sizes. It can be concluded that pupils' ability to solve mathematical problems significantly improved after the MEA was implemented in city schools.

Conclusion

MEA treatments had a significant favorable impact on student's ability to solve mathematical problems, according to the majority of studies on MEA's effects on this skill. However, according to several research, MEA adoption cannot enhance pupils' capacity for solving mathematical puzzles. This meta-analysis investigation revealed that the MEA intervention had a significant beneficial impact. Judging from the moderator variable, at the elementary school level the MEA effect is higher than at other levels. The sample size that can be used is more than thirty students. The effect of MEA on solving mathematical problems is higher in urban areas. While the educational level and demographics of the students did not affect the intervention's effect size in this study, the sample size was the variable that caused heterogeneity in that measure. The evaluation of the study features in this meta-analysis research advises Indonesian math teachers that more primary schools should use MEA implementation to improve students' mathematical problem-solving.

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