World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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Meta-analysis: The effect of learning models on mathematical problem-solving skills

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World Journal of Advanced Research and Reviews, 2024, 22(03), 1686–1692

Publication history: Received on 17 May 2024; revised on 25 June 2024; accepted on 27 June 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.22.3.1941

Abstract

Problem solving ability is one of the skills that need to be developed in students. Through searching the Google Scholar database, 75 journal articles were found that discussed mathematical problem-solving abilities. This study uses a meta-analysis design to determine the effect of applying several learning models on mathematical problem-solving abilities. Of all the articles obtained, there were 12 articles that met the predetermined criteria to be analyzed using the help of the online meta-analysis calculator application which can be accessed on the website https://meta-mar.shinyapps.io/meta-analysis-calculator/ so that an effect was obtained. combined sizes. Based on the interpretation of the combined effect size, it can be concluded that overall, the application of learning models from each study including: PBL, PjBL, Generative, and Geogebra-assisted has a strong influence on mathematical problem-solving abilities. There are also characteristics analyzed in this study including the year of research, educational level, and learning model. Statistically, it was found that the application of learning models to improve mathematical problem-solving abilities was influenced by the level of education and the learning model used.

Keywords: Problem Solving; Learning Models; Meta-Analysis; Mathematics; Education

1. Introduction

Problem solving ability is one of the skills that need to be developed in students. This is in line with the opinion Hamimi & Lasmita (2019) which states that one of the goals of learning mathematics is to train students' problem-solving skills. This is also in line with the National Council of Teachers of Mathematics which states that problem solving has three interpretations, namely: problem solving as a goal, as a skill and as a process (Hendriana, 2017). The statement is in line with mathematical problem-solving helping students apply principles, rules, and various systematic problem-solving strategies in mathematics (Somawati, 2018). The ability that is considered important for students to have, to face a world that continues to change is the ability that can be used to help students make decisions for themselves, as well as for their environment. The ability that can help students to make decisions is mathematical problem-solving ability.

Problem solving is the process of overcoming difficulties in order to achieve the expected goals. This refers to the fact that mathematics learning begins with an everyday problem orientation, involving students in the learning process, not just memorizing formulas, but to be able to understand how to solve problems (Pratiwi, 2019). Problem solving is a form of learning approach that is effective in shaping higher-order thinking processes and helping learners process the information received and compile it based on the knowledge they have about their environment (Bernard et al., 2018).

Mathematical problem solving ability is the achievement of individuals or groups in solving mathematical problems with the discovery method whose solutions are based on the stages of problem solving. The problem solving ability of students is still low, many students are not used to answering exam material in the form of non-routine exam questions, namely questions with mathematical problems that require reasoning and understanding of concepts (Hendri & Kenedi, 2018). Especially in the current era of the industrial revolution 4.0, mathematical problem solving skills are needed in

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all aspects of life. In addition, it is also important for students because it can make it easier for students to learn a material, and help students to solve the problems they face. With good problem solving skills, students may gain experience using the knowledge and skills they already have to be able to apply to solving non-routine problems (Hendri & Kenedi, 2018).

The 2018 survey results on numeracy, reading, and science skills conducted by the Program for International Student Assessment (PISA) showed that Indonesia ranked in the bottom 10 of 79 participating countries (Hewi & Shaleh, 2020). These results are supported based on the results of the 2015 survey on TIMSS regarding Indonesia's math problem solving ability ranked 49 out of 53 participating countries. The low problem solving ability is reinforced by the fact that students' problem solving skills have not been maximally trained (Handayani, 2017).

Based on the results of the analysis above, teachers have an important role in educating students. The application of learning strategies is one of the teacher's alternatives in the process of developing students' problem solving skills when learning mathematics (Abidin et al., 2020). Learning models can be developed situationally by considering several things including student characteristics, teaching materials, and the learning environment. This is in line with what Isrok'atun & Rosmala (2021) stated that the use of learning models is adjusted to the characteristics of teaching materials and student characteristics through the use of the learning environment available at school.

The learning model is a guide that teachers can use to carry out learning activities, because the learning model is a learning design pattern that describes systematically the learning steps to help students construct information, ideas, and build mindsets to achieve learning objectives. In general, the learning model acts as a guide in carrying out learning activities. In addition, the learning model also has a special role, among others, it can help teachers create the desired changes in student behavior.

Different studies on the same topic sometimes produce different, even contradictory results, and result in that conclusions about research questions can be subjective. Therefore, meta-analysis studies are needed to analyze and interpret such results to reach in-depth and convincing conclusions (Tamur et al., 2020). Meta analysis increases the likelihood that different readers will come to the same conclusion by calculating effect sizes and combining them into an objective formula (Hunter & Schmidt, 2004). According to Gough et al., a meta-analysis is evidence of a study that used rigorous and methodical research methods to answer research questions by examining previous primary studies (Khairunnisa & Juandi, 2022).

Based on this description, the author needs to conduct meta-analysis research: the effect of learning models on mathematical problem-solving skills, with the aim of finding out the effect of several learning models on mathematical problem-solving skills with a comparison of conventional learning models based on the characteristics of the learning model, level of education, and year of research. It is hoped that the results of the study will inform teachers about how to use learning models to improve mathematical problem-solving skills.

2. Material and methods

The study used a meta-analysis method through article reviews in national journals. Meta analysis is a statistical method used to systematically combine, analyze, and compile various studies to produce the latest findings and conclusions related to research results (Rohmatulloh et al., 2022). Retnawati et al. (2018) said there are several main steps taken to conduct meta-analysis, including (1) formulating research questions, (2) collecting studies as material for analysis, (3) calculating effect size, and (4) reporting.

The questions in meta-analysis relate to 4 things, namely measures of centering, pre-post comparisons, two-group comparisons, and correlations. In this study, the research question was formulated to compare two groups between the experimental group and the control group. After the research question has been formulated, the next step is to collect studies for analysis. In collecting studies, there are several things that need to be done starting from determining study criteria to coding. According to Retnawati et al. (2018) there are three main reasons for the importance of determining study criteria, including (1) the criteria can be used to guide the selection of which studies to use, (2) the criteria are important for determining the population related to making inferences, and (3) transparency related to the publication of meta-analysis. Some of the criteria established in this study include:

- Publication years range from 2013 to 2022.
- The selected article has been indexed by SINTA
- Articles with quasi-experimental research methods

- Primary study articles with populations at junior high, high school, and university levels
- Articles with statistical data such as sample size, mean, and standard deviation

The study collection was carried out by searching for articles on the Google Scholar database with the keywords "Mathematical Problem Solving", "Problem Solving Ability", and "Mathematical Problem-Solving Ability". From the search results, 75 articles were obtained which were then selected based on the predetermined study criteria, resulting in 12 articles as meta-analysis material. After obtaining articles that match the predetermined criteria, the next process is to code each article. Coding in this meta-analysis was carried out by collecting data in the form of authors, publication year, sample statistical data, mean, standard deviation, education level, and publication journal.

The next process is to calculate the effect size, the calculation uses the standardized mean difference, namely Hedges's g with the help of the online meta-analysis calculator application on the website https://meta-mar.shinyapps.io/meta-analysis-calculator/. The interpretation of the effect size results is as follows.

Table 1 Effect Size Interpretation

Effect Size	Interpretation
$0 \leq ES \leq 0{,}20$	Weak Effects
$0{,}20 < ES \leq 0{,}50$	Simple Effects
$0{,}50 < ES \leq 1{,}00$	Medium Effects
$ES > 1{,}00$	Strong Effects

After determining the effect size, then a homogeneity test is carried out to determine the analysis model to be used by looking at the p-value. If the p-value <0.05, then the distribution of the effect size used in the meta-analysis is heterogeneous, so the analysis model used is a random effects model. Meanwhile, if the p-value> 0.05, the effect size distribution used in the meta-analysis is homogeneous, so the analysis model used is a fixed effect model (Retnawati et al., 2018). The results of a meta-analysis based on studies involving different sample sizes will definitely produce good or biased results. Therefore, bias publication information is also needed. Funnel plot and Rosenthal's Fail-Safe N (FSN) are some techniques that can be used to identify and stop publication bias (Retnawati et al., 2018).

3. Results and discussion

This study aims to determine the combined effect size between the effects of innovative learning models on students' mathematical problem-solving skills. The list of articles used in this meta-analysis can be seen in Table 2.

Table 2 Articles used in Meta-analysis

Article Code	Title of Article	Name of Journal	Author and Year of Publication
A01	Penerapan Model *Problem Based Learning* (PBL) Terhadap Kemampuan Komunikasi dan Kemampuan Pemecahan Masalah Matematika Siswa Sekolah Menengah Pertama Lubuklinggau	Jurnal Pendidikan Matematika Rafkesia	(Yanti, 2017)
A02	Model Pembelajaran *Project Based Learning* Terhadap Kemampuan Pemecahan Masalah Matematika	Jurnal Formatif	(Nurfitriyanti, 2016)
A03	Pengaruh Pembelajaran Berbasis Masalah terhadap Kemampuan Pemecahan Masalah Matematis Siswa SMP	Jurnal Pembelajaran Matematika Inovatif	(Yuhani et al., 2018)
A04	Pengaruh Pembelajaran *Problem Based Learning* dengan Pendekatan Metakognisi terhadap Kemampuan Pemecahan Masalah Matematis	Mosharafa	(Elita et al., 2019)
A05	Pengaruh Pembelajaran Berbasis Masalah Terhadap Kemampuan Pemecahan Masalah Matematis Siswa SMA	Jurnal Pembelajaran Matematika Inovatif	(Ayubi et al., 2018)

A06	Pembelajaran *Problem Based Learning* untuk Meningkatkan Kemampuan Pemecahan Masalah Matematis dan *Self Efficacy* Mahasiswa Calon Guru	JNPM	(Sariningsih & Purwasih, 2017)
A07	Pengaruh Model Pembelajaran Generatif Terhadap Kemampuan Pemecahan Masalah Matematika	Jurnal Formatif	(Hakim, 2014)
A08	Peningkatan Kemampuan Pemecahan Masalah Matematis Siswa melalui Pembelajaran Berbasis Masalah	Mosharafa	(Sumartini, 2016)
A09	Peningkatan Kemampuan Pemecahan Masalah Matematis dan Kemandirian Belajar Siswa Melalui Pembelajaran Berbasis Masalah	Edumaspul	(Nasution & Mujib, 2022)
A10	Pengaruh Pembelajaran Problem Solving Model Polya Terhadap Kemampuan Memecahkan Masalah Matematika Mahasiswa	Jurnal Pendidikan	(Anugraheni, 2019)
A11	Penerapan Geogebra Untuk Meningkatkan Kemampuan Pemecahan Masalah Matematis Mahasiswa Program Studi Pendidikan Matematika Universitas Suryakancana	Jurnal Prisma	(Septian, 2017)
A12	Pengaruh Model Pembelajaran *Problem Based Learning* (PBL) Terhadap Kemampuan Pemecahan Masalah Mahasiswa	Aksioma	(Oktaviana & Haryadi, 2020)

The articles were then calculated effect size, standard error, and confidence interval based on the standardized mean difference, namely Hedges's g, using the help of an online meta-analysis calculator application that can be accessed through the website https://meta-mar.shinyapps.io/meta-analysis-calculator/. The calculation results can be seen in Table 3.

Table 3 Effect Size, Effect Size Interpretation, Standard Error, and Confidence Interval for each Article

Article Code	**Effect Size**	**Interpretation of Effect Size**	**Standard Error**	**Trust Interval**	
				Lower Limit	Upper Limit
A01	1,4860	Strong	0,5009	0,9851	1,9869
A02	0,9965	Medium	0,4983	0,4982	1,4948
A03	0,4386	Simple	0,4813	-0,0428	0,9199
A04	0,8634	Medium	0,7066	0,1568	1,5700
A05	0,5190	Medium	0,5533	-0,0344	1,0723
A06	1,5277	Strong	0,5398	0,9878	2,0675
A07	1,2450	Strong	0,4839	0,7612	1,7289
A08	0,5790	Medium	0,4721	0,1070	1,0511
A09	1,4447	Strong	0,5721	0,8725	2,0168
A10	1,3795	Strong	0,5667	0,8129	1,9462
A11	1,9590	Strong	0,6121	1,3469	2,5711
A12	1,3564	Strong	0,6076	0,7488	1,9640

Based on Table 3, there are seven articles that have an effect size of more than 1.00 with a strong category, four articles have an effect size between 0.50 and 1.00 with a medium category, and one article that has an effect size between 0.20 and 0.50 with a modest category. Thus, seven studies showed a strong effect in improving problem solving skills with

learning models in each of these studies, namely the Problem Based Learning (PBL) learning model, the Generative learning model, and the Geogebra-assisted learning model. The four studies showed a moderate effect in improving mathematical problem-solving skills with learning models including Project Based Learning and Problem Based Learning learning models. Furthermore, one study showed a modest effect on mathematical problem-solving ability with the Problem Based Learning learning model.

Starting with testing the homogeneity of the primary studies, an estimation model can be created to measure the pooled effect of the primary studies as a whole. The homogeneity test was conducted by analyzing the heterogeneity of the effect size distribution. The results of the heterogeneity analysis of the effect size distribution of all articles can be seen in Table 4.

Table 4 Heterogeneity of Effect Size Distribution

Heterogeneity				
Chi-Squared	df	P-Value	I-Squared	Tau-Squared
32.35	11	0,00007	66%	0,1461

Based on Table 4, the p-value <0.05 means that the effect size distribution of all primary studies used in this meta-analysis is heterogeneous. Therefore, the estimation model used to determine the combined effect size value is the random effect (RE) model. Next, Table 5 will present the results of the meta-analysis of primary studies using the random effect (RE) estimation model.

Table 5 Meta Analysis Results based on Random Effect (RE) Model

Effect Size and Trust Interval				**Test of Null**	
Effect Size	Standard Error	Lower Limit	Upper Limit	Z-Value	P-Value
1,1386	0,2996	0,8391	1,4382	8,37	0,0000

Based on Table 5, the results of the meta-analysis obtained a p-value of 0.0000 <0.05, which means it can be concluded that overall, the application of learning models from each study has a more significant effect on mathematical problem-solving skills compared to the application of conventional learning models. This study also produced an effect size of 1.1386 which means it falls into the strong category. Thus, it can also be concluded that overall, the application of the Learning Model from each study has a strong influence on mathematical problem-solving ability. For a more in-depth study, further meta-analysis was conducted for each study characteristic including education level, research year, and learning model used. The results of the analysis can be seen in Table 6.

Table 6 Meta-analysis results for each study characteristic

Characteristics	**Category**	**N**	**Henges' g**	**Test of Null**		**Trust Interval**	
				Z-Value	P-Value	Lower Limit	Upper Limit
Education Level	Junior High School	4	1,0579	4,12	0,0260	0,2398	1,8761
	Senior High School	4	0,8433	4,87	0,0165	0,2926	1,3939
	PT	4	1,5466	11,56	0,0014	1,1209	1,9724
Year of Study	2013 - 2017	6	1,2778	6,63	0,0012	0,7824	1,7732
	2018 - 2022	6	0,9880	5,21	0,0034	0,5002	1,4758
Learning Model	PBL	9	1,0582	6,79	0,0001	0,6990	1,4173
	PjBL	1	0,9965	3,92	0,0000	0,4982	1,4948
	Generative	1	1,2450	5,04	0,0000	0,7612	1,7289
	Geogebra	1	1,9590	6,27	0,0000	1,3469	2,5711

Based on Table 6, for the characteristics of the education level, it is concluded that mathematical problem-solving ability is strongly influenced at the junior high school and university education levels with an effect size of 1.0579 and 1.5466, respectively. However, at the SMA/MA education level only moderate influence results were obtained with an effect size value of 0.8433. As for the characteristics of the research year, it was concluded that mathematical problem-solving ability was strongly influenced in the 2013-2017 research year with an effect size value of 1.2778 and moderately influenced in the 2018-2022 research year with an effect size value of 0.9880. Next, for the characteristics of the learning model, information was obtained that mathematical problem-solving ability was strongly influenced by the PBL learning model, generative learning model, and geogebra-assisted learning model with an effect size value of 1.0582; 1.2450; and 1.9590, respectively. While mathematical problem-solving ability is only moderately influenced by the PjBL learning model with an effect size value of 0.9965.

The results of the meta-analysis in this study may be biased. Therefore, it is necessary to detect publication bias in this study. Publication bias was detected by using the Fail-Safe N value. Of the 12 study articles analyzed, the FSN value was 880. Then by using the formula $\frac{FSN}{5K+10}$, where k is the number of articles analyzed, a value of 12.5714> 1 was obtained. Therefore, it can be concluded that the studies used in this meta-analysis meet sufficient tolerance for publication bias.

4. Conclusion

The results of the meta-analysis using 12 study articles that discuss the effect of learning models on mathematical problem-solving skills show that the combined effect size of the primary study is 1.1386 which is classified as a strong category. Thus, it can be concluded that overall, the application of learning models in each study, including Problem Based Learning, Project Based Learning, Generative, and Geogebra-assisted learning models, has a strong and significant effect on mathematical problem-solving skills compared to the application of conventional learning models.

In terms of some study characteristics, the improvement of mathematical problem-solving ability is influenced by the level of education, where at the junior high school and PT education level is strongly influenced and at the senior high school level is moderately influenced. In addition to the level of education, the effect of the learning model on mathematical problem-solving ability was found to have a different effect based on the research year. In the 2013-2017 research year, the learning model had a stronger effect than in the 2018-2022 research year. These findings contribute to teachers to apply the right learning model and have a good effect in improving mathematical problem-solving skills. However, the authors hope that there will be further research on this study.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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