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Meta-Analysis: The Effect of Problem-Based Learning Assisted GeoGebra Software on Students Mathematic Ability

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Abstract

Problem Based Learning (PBL) is a learning model that is often used in learning mathematics. This meta-analysis study was conducted to summarize the effect of PBL with the help of GeoGebra software on students' mathematical abilities. Related databases were searched for studies that met the inclusion criteria. The estimation method uses a random-effect model with a 95% confidence interval. This study analyzed 5 primary studies published between 2016 and 2020 using the posttest-only group design experimental research method, and 320 students were involved. The Comprehensive Meta-Analysis (CMA) program was used to assist the analysis. As a result of the study, the overall effect size was 1.32 (strong effect) with a standard deviation of 0.021. Analysis of study characteristics revealed that the influence of the PBL model assisted by GeoGebra applications had a strong effect on the condition of the sample size of 1-40 students, secondary school education level and on mathematical problem-solving abilities. This finding is considered by practitioners of mathematics education to implement it in mathematics learning.

Keywords: Problem Based Learning (PBL), Software Geogebra, Meta-Analysis

Abstrak

Problem Based Learning (PBL) merupakan model pembelajaran yang sering digunakan dalam pembelajaran matematika. Studi meta analisis ini dilakukan untuk merangkum pengaruh PBL dengan bantuan software GeoGebra terhadap kemampuan matematika siswa. Database terkait dicari untuk studi yang memenuhi kriteria inklusi. Metode estimasi menggunakan model *random effect* dengan interval kepercayaan 95%. Studi ini menganalisis 5 artikel sebagai studi primer antara 2016 dan 2020 dengan menggunakan metode penelitian eksperimental desain kelompok posttest-only, dan melibatkan 320 siswa. Program Comprehensive Meta-Analysis (CMA) digunakan untuk membantu analisis. Sebagai hasil penelitian, ukuran efek keseluruhan adalah 1,32 (efek kuat) dengan standar deviasi 0,021. Analisis karakteristik penelitian mengungkapkan bahwa pengaruh model PBL berbantuan aplikasi GeoGebra berpengaruh kuat pada kondisi ukuran sampel 1-40 siswa, tingkat pendidikan sekolah menengah dan terhadap kemampuan pemecahan masalah matematis. Temuan ini menjadi pertimbangan para praktisi pendidikan matematika untuk menerapkannya dalam pembelajaran matematika.**Kata kunci:** Problem Based Learning (PBL), Software Geogebra, Meta-Analysis.

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INTRODUCTION

Mathematics is one of the subjects that must be mastered by students. Mathematics is not just about numbers, it is much broader than that. Mathematics forms a logical and critical way of thinking that is needed by society, especially in facing the challenges of an increasingly changing era, especially in the field of technology. Technology is now growing rapidly, everyone uses technology so that technology is very familiar with people's lives. Concepts in mathematics are closely related to the field of technology, as well as technology itself if optimized, can help students in learning mathematics in understanding mathematical concepts which are an important part of the mathematics learning process.

In learning mathematics, the fact is that students still do not understand mathematical concepts. This can be caused by the low mathematical ability of students due to the selection of learning models

that are less effective. However, as technology develops, teachers innovate in terms of determining learning models and even collaborating learning with various technologies such as software media, online media, and other technologies. One of the learning models chosen is the Problem Based Learning (PBL) learning model with the help of software media technology.

PBL is a learning model by presenting students with problems in the learning process. In recent years, there seems to be an increase in the application of problem-based learning. Many researchers focus one of them on the influence of PBL with the help of technology, one of which is GeoGebra software on mathematical abilities in secondary education. The implementation of PBL is increasingly popular in mathematics education, various studies that focus on PBL with the help of GeoGebra ensure the effectiveness of PBL with the help of GeoGebra by using experimental or quasi-experimental designs (Afridiani et al., 2020; Aisyah, 2016; Amalia et al., 2020; Belladina et al., 2019; Rahmadani & Acesta, 2017). However, other studies have found that PBL is no more effective in learning than conventional learning (Dewanto et al., 2018; Wardhani et al., 2016).

Until now, there has been no single study that confirms that PBL with the help of GeoGebra software consistently shows its effectiveness on students' mathematical abilities in learning mathematics. The study category variables of identified PBL effectiveness show the heterogeneity of the study (Demirel & Dagyar, 2016). In addition, the effectiveness of PBL is moderated by the accompanying categorical variables (Yunita et al., 2020). There is no primary study that investigates the variation of results from the effect of PBL assisted by GeoGebra software on students' mathematical abilities. On the other hand, practitioners need a convincing conclusion that under what conditions PBL with the help of GeoGebra software can improve students' mathematical abilities.

Meta-analysis was implemented to summarize and analyze the findings of the extent to which the characteristics of the primary study moderated the relationship between PBL and mathematical ability, among which this study focused on the ability to understand concepts, problem-solving abilities, and representation skills. These findings will affect the implementation of PBL even better in the future. Meta-analysis is seen as a popular way to combine results from several primary studies, compare multiple treatments (White, 2015) summarize and explains them more broadly (Borenstein, M., Hedges, L. V., Higgins, J. P. T., 2009; Green, 2005). The meta-analysis procedure ignores subjective interpretations of various research reviews on the same topic (Rothstein et al., 2006). Furthermore, meta-analyses provide cumulative evidence by reducing the distortionary effects of the primary studies thereby reducing conflicts of different findings, and helping to create understanding and develop a theory by identifying relationships between study characteristics (Grant & Hunter, 2006).

In the literature, previous meta-analysis reports provide a general overview of the effects of implementing PBL compared to conventional methods (Demirel & Dagyar, 2016). These studies have not specifically examined the effect of PBL on students' mathematical abilities, besides that they have not involved the role of technology, especially GeoGebra software. This research complements previous research that has not involved the use of technology, one of which is the GeoGebra software in the use

of PBL on students' mathematical abilities. The work of the meta-analysis is to analyze various primary studies on the same topic allowing for variations in effect sizes (Ndiung et al., 2021; Tamur et al., 2020). This study aims to determine the magnitude of the effect of PBL assisted by GeoGebra software on students' mathematical abilities and examine the extent to which study characteristics moderate the effectiveness of PBL assisted by GeoGebra software. This explanation shows the importance of conducting a comprehensive meta-analysis on the effectiveness of PBL assisted by GeoGebra software on the mathematical abilities of students in Indonesia from 2016 to 2020. It is necessary to evaluate their use and see the overall trend more clearly.

METHOD

Research Design

This study uses a meta-analysis that combines two or more published primary studies to integrate the findings (Glass, 2015; Grant & Hunter, 2006). This research has analyzed the primary study that questioned the effect of PBL assisted by GeoGebra software on students' mathematical ability. Like the general meta-analysis steps that have been applied by (Borenstein, 2009) and (Pigott, 2012), this study also followed similar stages, namely determining inclusion criteria, collecting data and coding variables, and statistical analysis.

Data Collection

Meta-analysis study was characterized by a thorough literature search. A clear definition of the hypothesis to be tested provides a framework for the search. It is important to obtain all relevant studies, as missing studies can lead to bias in the study. Empirical data were obtained from published articles and abstracts were identified by computer literature search from electronic databases including Researchgate (https://www.researchgate.net/) and Google Scholar (https://scholar.google.co.id/schhp?hl=en).n. This stage found 25 studies on the effect of PBL assisted by GeoGebra software on students' mathematical abilities. Based on the inclusion criteria, 5 primary studies were eligible for analysis. Some studies compare more than one comparison group.

Data Coding

The instrument used in this study was a variable coding sheet. The coding process in addition to helping researchers in analyzing data, also avoids data being forgotten. The coding in data analysis includes information extracted from the primary study, namely the year of research, sample size, a combination of models used, and education level. To ensure that the data entered without error, the two coders filled out the coding form separately and then compared it. If there is still data that is not the same, it will be re-verified.

Statistical Analysis

The data were statistically analyzed by following the steps of Borenstein & Hedges (2009), namely: (a) determine the effect size of each study; (b) determine the effect size heterogeneity test; (c) determine publication bias, and (d) calculate the p-value. To assess the extent to which the

characteristics of the study moderate PBL, it was carried out after it was known that the estimated model was a random-effect model. Applications that help with data analysis are Comprehensive Meta-Analysis (CMA) programs. Hedge's equation is used to determine the effect size index. Effect size interpretation, using the classification of Cohen et al. (2007) as shown in Table 1.

Tabel 1. Effect Size Interpretation

Effect Size Range (ES)	Interpretation
ES ≤ 0,20	Weak Effect
0,20 < ES≤0,50	Simple Effect
0,50 < ES≤1,00	Medium Effect
ES > 1,00	Strong Effect

CMA can calculate the value of Z which is used to test the significance of the effect of PBL with the help of GeoGebra software on students' mathematical abilities and provide an average effect size with confidence intervals for each class of variables and homogeneity between groups, namely the Qb value. If Zcount > Ztable with p<0.05, the null hypothesis is rejected (Borenstein, M., Hedges, L. V., Higgins, J. P. T., 2009). This indicates that the application of PBL assisted by GeoGebra software on students' mathematical abilities produces a positive effect size on students' mathematical abilities compared to conventional approaches. Furthermore, the most important decision to be made when conducting a meta-analysis is whether to use a fixed-effect or random-effect estimation model (Kong et al., 2014). The fixed-effect model indicates that the effect sizes between studies or study groups are homogeneous. The random-effect model was used when the effect sizes were statistically heterogeneous (Qb>χ1,02; p<0.05). Rejecting Qb implies that the effect sizes between studies or study groups may not measure the same population parameters (Borenstein, 2009). In other words, there are statistically significant differences in the combined effect sizes for each study characteristic group (Khan, 2020).

RESULT AND DISCUSSION

In this study, the number of articles used was under the objectives, namely 5 articles.

Table 2. Article Data

Code	Citation	Statical Data							Level
		PBL Asisted Geogebra			Conventional				
		Sample Size	Mean	Standard Deviation	Sample Size	Mean	Standard Deviation	t-Value	
J01	Aisyah, 2016	27	81,91	11,51	27	64,57	15,09	4,57	SMP
J02	Ramdhani & Narpila, 2018	38	75,24	6,902	38	64,26	8,186	67	SMA
J03	Belladina et.al, 2019	27			28			0,145	SMA
J04	Amalia et.al, 2020	32	79,82		32	71,32		0,287	SMA
J05	Afridiani et.al, 2020	36	12,5	36,096	35	11	28,076	19,50	SMP

Based on the table above, there were 5 articles that used the posttest only group design research method. The experimental class used is PBL with the help of GeoGebra software, with research subjects at the high school level. The main objective of this study is to find a measure of the combined effect of learning using PBL using GeoGebra software on students' mathematical abilities. Effect Size is used to show the magnitude of an effect from the existence of a treatment. The relationship between variables in this meta-analysis is between the effect of the Geogebra software PBL model and student learning outcomes in Mathematics learning. Based on the results of the study, it can be saw that PBL has a very positive influence in improving student learning outcomes in learning mathematics. Of the 5 articles, there are 3 articles that have a great influence, the results of the study also show that the junior high school level has a greater influence. In addition, the sample size also affects the results of the study. The summary of the research results is presented in the table.

Table 3. Article Of Effect Size Data

Primary Study Author	**Effect Size**	**Variance**	**Confidence Interval**	
			Lower Limit	**Upper Limit**
Aisyah, 2016	1,27	0,09	0,70	I,85
Ramdhani & Narpila, 2018	15,21	1,57	12,76	17,67
Belladina et.al, 2019	0,04	0,07	-0,48	0,56
Amalia et.al, 2020	0,07	0,06	-0,41	0,56
Afridiani et.al, 2020	4,58	0,20	3,70	5,46

Based on the calculation of the effect size obtained, the average effect size is 1.32. it means that the based learning model assisted by Geogebra software is effective in improving student learning outcomes in high school with a strong effect category. Our next step will be to analyze publication bias based on the random-effect model, namely examining whether there is a tendency for journals to publish only significant studies that lead to meta-analyses that do not describe the population (Borenstein, 2009) publication bias can be determined by examining the study funnel plot in figure 1.

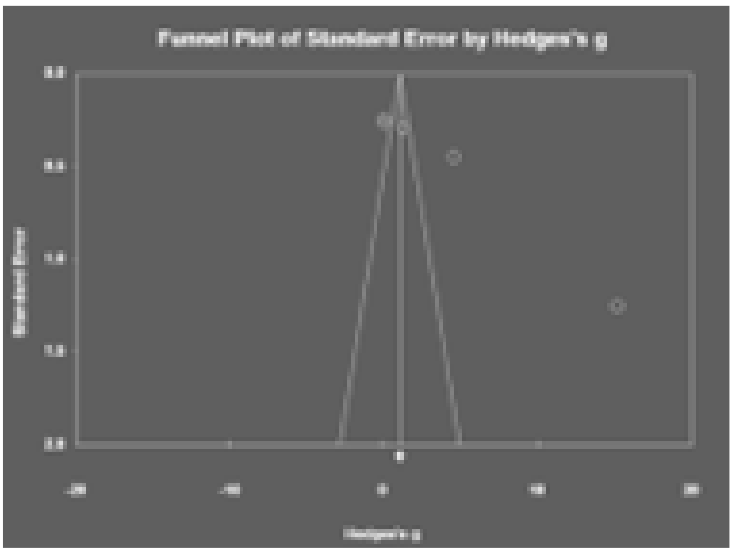

Figure 1. Publication Bias

Figure 1 shows that the effect is not completely symmetrical around the vertical line. Furthermore, it has been determined that the random effects model is the chosen estimation model. Table 4. Is a summary of the results of the analysis.

Table 4 effect size

Study name	Statistic for each study						
	Hedges's g	Standard error	variance	Lower limit	Upper limit	Z-value	P-value
Aisyah, 2016	1,274	0,295	0,087	0,696	1,852	4,320	0,000
Ramdhani & Narpila, 2018	15,215	1,255	1,574	12,755	17,674	12,125	0,000
Belladina et.al, 2019	0,0039	0,266	0,071	-0,482	0,560	0,146	0,884
Amalia et.al, 2020	0,0071	0,247	0,061	-0,413	0,555	0,287	0,774
Afridiani et.al, 2020	4,578	0,450	0,203	3,696	5,461	10,168	0,000
	1,021	0,145	0,021	0,737	1,305	7,045	0,000

Consequently, the variation in effect size was evaluated from the identified study characteristics namely: year of publication, sample size, education level, source of publication, and the combination of learning models used. Table 4 is a summary of the results of the analysis. The results of the study indicate that the overall effect size of the study is 1.32 which reflects that the application of PBL assisted by GeoGebra software on students' mathematical abilities in conventional classes.

CONCLUSION

This research was conducted to determine the effectiveness of the problem-based learning model with the help of Geogebra software on students' mathematical abilities. based on a random-effects model with a 95% confidence interval the combined effect size was found to be 3.79 with a standard error of 1.32. This finding shows that the application of PBL assisted by technology in the form of Geogebra software produces a measure of the effect of students' mathematical abilities including the ability to understand the concept of problem-solving ability and representative ability that is greater than the conventional approach. The standard error of 1.32 which is quite high indicates that the effect is not significant because there are variables in the effect size of each study. As a result, an examination of the reasons for the variation in effect size was carried out by evaluating the relationship between study characteristics and the effectiveness of PBL with the help of GeoGebra software. First, based on the year of publication of the journal, sample size, education level, source of publication, and the combination of learning models used.

However, this is only supported by the primary studies which can be reached using the specified database, and the primary studies contain statistical information for effect size transformations. There are still many related studies that have not been analyzed because the required statistical information is not sufficient. This study has not reached other characteristics that may be related to the effectiveness of PBL assisted by GeoGebra software on students' mathematical abilities, such as treatment duration,

research location, learning materials, and others. As a result, this finding does not mean to describe the overall effectiveness of PBL assisted by GeoGebra software on students' mathematical abilities. As a suggestion, further researchers need to conduct further analysis regarding the effectiveness of PBL assisted by GeoGebra software on students' mathematical abilities seen from the various characteristics of these studies and by analyzing more studies and various research methods so that they can reach the required variables.

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