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# Meta-Analysis: The Effect of Problem-Based Learning Models on Students' Understanding Mathematical Concepts in Indonesia

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**A B S T R A C T**

One of the essential abilities in learning mathematics is understanding mathematical concepts. Through sinta 1-5, the author obtained 55 journal articles discussing the influence of applying learning models on students' ability to understand mathematical concepts. This research uses a meta-analysis design to determine how implementing the Problem-Based Learning (PBL) learning model affects students' ability to understand mathematical concepts. Of all the articles the author obtained, 12 met the inclusion criteria for analysis using the website https://www.meta-mar.com/, so a sizeable combined effect size was obtained. Based on the interpretation of the combined effect size, it can be concluded that overall, the implementation of the PBL learning model does not strongly influence students' ability to understand mathematical concepts. There are also study characteristics analyzed in this research, including a year of research, level of education, and research location. Statistically, it was found that the application of learning to improve students' mathematical literacy skills was not influenced by educational level, year of research, and research location.

Keywords: Meta-Analysis, Understanding of Mathematical Concepts, Problem-Based Learning

## 1. Introduction

One of the main goals of learning mathematics is for students to have a good understanding of mathematical concepts, explain the relationship between concept elements, and apply these concepts appropriately in solving a problem (Sayekti, 2020). Warniasih (2018) also stated that one of the goals of learning mathematics is to help students understand mathematical concepts and explain their relationships so that they can solve problems in everyday life.

Based on these objectives, understanding concepts is an essential ability in learning mathematics. Teachers who act as facilitators in the learning process need to realize that the material taught to students is not just memorized but involves concepts that must be understood. In this way, students will deeply understand these concepts and not just memorize them.

Pratiwi (2019) explains that understanding mathematical concepts has many benefits and a significant influence on students' education, such as having an essential role in facilitating understanding and organizing information, promoting effective teaching and learning, and helping students learn things. New and complex in a more structured way. Meanwhile, according to Sayekti (2020), understanding mathematical concepts has several important aspects, namely: (1) The ability to explain mathematical concepts and related facts in a more straightforward and easier-to-understand way; (2) the ability to form logical relationships between facts and mathematical concepts; (3) Recognize the relationship between concepts that have been understood and other concepts; (4) Realizing that mathematical principles are related to the world of work and have applications in everyday life.

According to Pratiwi (2019), students can be said to have understood a concept when they can recognize and abstract the same characteristics in the idea, which are the characteristics of the concept being studied. Apart from that, they can also generalize the concept, meaning they realize that the idea's existence is not limited to particular objects or events but is general and can be applied to different situations. Thus, understanding mathematical concepts includes the ability to simplify and explain concepts, relate them logically, recognize relationships with other concepts, and be able to generalize these concepts to have a more abstract and general understanding.

Students' success in understanding mathematical concepts that they consider difficult is greatly influenced by the learning process they experience. As Wahyudi et al. (2018) argue, several factors can cause this problem to arise. First, learning is still focused on the role of the teacher, so students have limitations in developing their thinking processes and abilities. Second, there is a lack of linking the material to real life, so students have difficulty applying the concepts they have learned to solve everyday problems. Third, the discussion method designed by the teacher was less successful because only a few group members were actively trying to solve the problem. To overcome this problem so that it does not continue, the solution is to use a suitable learning model, one of which is the Problem-Based Learning (PBL) learning model.

PBL is an alternative learning method that can help students develop thinking skills through problems relevant to their daily lives (Sayekti, 2020). This learning model has various benefits, including improving students' understanding of mathematical concepts, logical, critical, and analytical thinking abilities, and the ability to explore knowledge when facing problem-based mathematics problems (Yuliani et al., 2018). PBL begins by introducing a real problem as a learning context so that students can learn to think critically, develop problem-solving skills, and gain knowledge. Thus, the PBL model shifts the focus of learning from teachers to students. PBL is a teaching approach emphasizing real problems as a learning context so students can develop critical thinking, problem-solving, and knowledge-acquisition skills (Kurnia D et al., 2014).

According to Sudia et al. (2017), PBL is a learning model that allows students to be involved in understanding mathematical concepts. In problem-based learning, students can develop thinking skills such as reasoning, communication, and connections to solve problems. This learning model is very suitable for learning mathematics because most students see mathematics as a complex problem. Apart from that, according to Warniasih and Nuryani (2018), PBL has the concept that learning objectives can be achieved by emphasizing problems that are authentic, relevant, and presented in a context. Through this learning, students can understand the concepts and principles of a problem.

Argawi and Pujiastuti (2021) state that concepts are the basis for understanding principles and theories. Therefore, students' understanding of mathematical concepts is essential, and learning models appropriate to current conditions, such as Problem-Based Learning (PBL), need to be implemented. Many studies have been conducted on PBL, which raises questions regarding the diverse research results. Therefore, a systematic method is needed to obtain conclusions in the form of aggregating the results of these studies, such as using meta-analysis. Meta-analysis is a study conducted by researchers to summarize data from previous studies and review and analyze the results of these studies. The purpose of meta-analysis is to produce a new theory or findings that can strengthen the results of previous research. A. Hidayatul Asror previously conducted similar research with the title "Meta-Analysis: PBL," which tested the effect of PBL on mathematics skills in various subjects, levels of education, subject matter and different media. However, the research that will be carried out this time will be more specific, namely examining the influence of PBL on students' understanding of concepts.

Based on the explanation above, this research aims to examine the effectiveness of problem-based learning (PBL) in improving students' comprehension abilities and understanding of mathematical concepts. This research will consider various levels of education and relevant subject matter. Like other similar research, this meta-analysis is expected to provide benefits in the field of education, especially for mathematics teachers. With the results of this research, teachers can choose suitable learning materials and media to use and measure mathematics skills appropriately when implementing PBL in mathematics learning.

## 2. Methodology

Researchers used a meta-analysis method in this research by reviewing articles from national journals. A meta-analysis is a statistical approach that systematically combines, analyzes, and synthesizes several studies to obtain the latest findings and conclusions based on the study's effects (Sampurnaningsih et al., 2020). Borenstein et al. (2009) suggest several stages in the meta-analysis, including determining inclusion criteria for the studies to be analyzed, empirical data collection procedures, coding study variables, and the statistical techniques used. Primary studies related to the PBL (Problem-Based Learning) model and students' ability to understand mathematical concepts have been reviewed in this research. The articles included in this primary study met the predetermined inclusion criteria, namely:

1. The range of article publication years is from 2019 to 2023.
2. Articles conducting research studies in Indonesia published in journals indexed by SINTA.
3. Articles with quasi-experimental research methods and randomized control group pretest-posttest design, randomized control group posttest only design, nonequivalent group pretest-posttest design, static group design, and nonequivalent group design posttest only.
4. Articles with primary study populations, namely middle school, high school, and university students in Indonesia.
5. Study articles with statistical data on primary studies, namely sample size, mean and standard deviation.

To search for articles, use various databases such as Google Scholar, Garuda Portal, and Sinta Ristekbrin using keywords such as "Problem-Based Learning," "Understanding Mathematical Concepts," "PBL, Ability to Understand Mathematical Concepts," "Problem-Based Learning," and "Mathematical Concepts." From 2019 to 2023, 55 articles were found through this search. From these articles, selection was carried out based on predetermined inclusion criteria, and finally, 12 articles were found relevant to this research at the junior high school level. /MTs, high school/equivalent, and tertiary institutions. Therefore, 12 study articles were used in this meta-analysis research.

Then, the researcher carried out the study coding process. To do this, a research instrument is used in the form of a coding protocol consisting of a coding form that can be paper or computerized, as well as a coding manual that contains guidelines on how to code each item according to the data in the original study (Wilson & Demetriou, 2007). The study coding process includes some information that will be used in the meta-analysis, such as study code, author's name, year of publication, mean, standard deviation, and sample size for the experimental group and control group. In addition, the research year is divided into two categories, namely 2019-2020 and 2021-2023. Education levels are divided into three categories: SMP/MTs, SMA/MA/SMK, and College. Meanwhile, journal publication locations are divided into two categories, namely Java Island and outside Java Island.

After completing the coding process, the author then calculated the effect size. This study wants to measure the differences between two independent groups, namely the experimental group that received the PBL learning model and the control group that received learning other than the PBL model, and considering that the primary study used had a small sample size and standard deviation for the sample, the effect size used in this research is an effect size based on a standardized mean difference, namely Hedges's g (Fritz et al., 2012). To interpret the effect size, this meta-analysis research will use the classification proposed by Cohen, which is as follows (Cohen et al., 2007).

**Table 1. Interpretation of Effect Size**

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

After calculating the effect size, the next step is to carry out a homogeneity test to determine the analysis model to be used. This homogeneity test was carried out using previous research's p-value on the Q-statistic (Greenhouse & Iyengar, 2009; Retnawati et al., 2018). If the p-value is <0.05, then the distribution of effect sizes from the primary studies used in the meta-analysis shows heterogeneity, and the analysis model used is a random effects model. Meanwhile, if the p-value is > 0.05, the effect size distribution is homogeneous, and the analysis model used is a fixed effects model (Retnawati et al., 2018).

Furthermore, in order for the studies used in this meta-analysis to be representative of all studies that address the same research question, as well as to avoid claims that only studies with significant results are published and used in this meta-analysis, authors need to detect and address publication bias (Greenhouse & Iyengar, 2009). One method to detect and overcome publication bias is through the funnel plot and Rosenthal's Fail-Safe N (FSN) (Retnawati et al., 2018). The first step in detecting publication bias is to use a funnel plot. Suppose the distribution of study effect sizes is not symmetrical or has some asymmetry. In that case, Rosenthal's Fail-Safe N (FSN) is used to help determine the presence of potential publication bias (Tamur et al., 2020). The authors can continue the analysis process if there is no significant publication bias.

The author can carry out a null hypothesis test using a predetermined analysis model. If the p-value <0.05, then the null hypothesis is rejected, which means that the application of the PBL learning model significantly influences students' ability to understand mathematical concepts compared to conventional and other learning models. Suppose the analysis model used is a random effects model, which shows differences in study characteristics. In that case, the author can analyze the study characteristics and interpret the results (Borenstein et al., 2009).

## 3. Result and Discussions

This research aims to determine the size of the combined effect of applying the PBL model on students' ability to understand mathematical concepts to obtain results regarding the effect of applying the PBL model on students' ability to understand mathematical concepts. Before knowing the overall effect size, you must write a list of studies used in the meta-analysis. The following is a list of studies included in this research.

**Table 2. Studies used in the Meta-Analysis**

| Study Code | Study Title | Journal Name |
|---|---|---|
| Study 1 | Pengaruh Penerapan Model Pembelajaran Problem Based Learning Terhadap Pemahaman Konsep Matematis Peserta Didik Kelas XI IPA SMAN 1 Kecamatan Lareh Sago Halaban<br>https://ejournal.unp.ac.id/students/index.php/pmat/article/view/13300 | Jurnal Edukasi dan Penelitian Matematika |
| Study 2 | Efektivitas Model Pembelajaran Problem-Based Learning dan Think Pair Share Berbantuan Geogebra Terhadap Kemampuan Pemecahan Masalah Matematis<br>https://e-journal.ivet.ac.id/index.php/matematika/article/view/930 | Journal of Medives: Journal of Mathematics Education IKIP Veteran Semarang |
| Study 3 | Pembelajaran Model Problem Based Learning Terhadap Kemampuan Pemahaman Konsep Matematis Siswa<br>http://www.fkip-unswagati.ac.id/ejournal/index.php/snpm/article/view/853 | In Prosiding Seminar Nasional Pendidikan Matematika (SNPM), |
| Study 4 | Pengaruh Model Problem Based Learning Terhadap Kemampuan Pemahaman Matematis Ditinjau Dari Kemampuan Awal Matematis Siswa<br>https://jurnal.untirta.ac.id/index.php/Tirtamath/article/view/8892 | Tirtamath: Jurnal Penelitian dan Pengajaran Matematika |
| Study 5 | Pengaruh Model Problem Based Learning Terhadap Pemahaman Konsep Matematis Siswa<br>http://repository.lppm.unila.ac.id/16285/ | Jurnal Pendidikan Matematika, Universitas Lampung |

| | | |
|---|---|---|
| Study 6 | Pengaruh Model Pembelajaran Problem Based Learning (PBL) terhadap Kemampuan Pemahaman Konsep Matematis Siswa Kelas XI SMA Swasta Kampus Nommensen Pematangsiantar<br>https://jonedu.org/index.php/joe/article/view/2453 | Journal on Education |
| Study 7 | Pengaruh Model Problem Based Learning Berbasis Lembar Kerja Peserta Didik Terhadap Kemampuan Pemahaman Konsep Matematis<br>http://jurnal.ugj.ac.id/index.php/Euclid/article/view/2532 | Jurnal Euclid |
| Study 8 | Komparasi Model Pembelajaran Problem Based Learning dan Inquiry Based Learning Ditinjau dari Kemampuan Pemahaman Konsep dan Pemecahan Masalah Matematika Siswa dalam Pembelajaran Segiempat<br>https://www.j-cup.org/index.php/cendekia/article/view/346 | Jurnal Cendekia: Jurnal Pendidikan Matematika |
| Study 9 | Pengaruh Model Problem Based Learning Terhadap Pemahaman Konsep Matematis Siswa<br>http://repository.lppm.unila.ac.id/16285/ | Jurnal Pendidikan Matematika Unila |
| Study 11 | Model Pembelajaran Problem Based Learning (Pbl): Efeknya Terhadap Pemahaman Konsep Dan Berpikir Kritis<br>http://ejournal.radenintan.ac.id/index.php/IJSME/article/view/4366 | Indonesian Journal of Science and Mathematics Education |
| Study 12 | Pengaruh Model Problem Based Learning Dengan Poster Session Terhadap Pemahaman Konsep Dan Komunikasi Matematika Mahasiswa<br>http://jurnalbeta.ac.id/index.php/betaJTM/article/view/59 | Beta, UIN Suska Riau |
| Study 13 | Pengaruh Model Pembelajaran Problem Based Learning (PBL) Terhadap Kemampuan Pemahaman Konsep Matematis Siswa<br>https://ejurnal.univalabuhanbatu.ac.id/index.php/al-khawarizmi/article/view/533 | Al-Khawarizmi: Jurnal Pendidikan Matematika |

Reference: (Retnawati, Apino, Kartianom, Djidu, & D, 2018)

The calculations were then continued using the meta-mar platform, so research data was obtained for each study according to the Hedges' g values listed in Table 3 below.

**Table 3. Effect size, Interpretation of Effect Size, Standard Error, and Confidence Interval of Each Study**

| Study Code | Year of Publication | Effect Size | Interpretation of Effect Size | SE | Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Upper |
| Studi 1 | 2022 | 0.59 | Medium effect | 0.2538 | 0.0926 | 1.0875 |
| Studi 2 | 2020 | 1.3251 | Strong effect | 0.3015 | 0.7341 | 1.9160 |
| Studi 3 | 2019 | 0.8755 | Medium effect | 0.2706 | 0.3451 | 1.4059 |
| Studi 4 | 2020 | 0.0500 | Weak effect | 0.3790 | -0.6929 | 0.7928 |
| Studi 5 | 2019 | 1.2409 | Strong effect | 0.2805 | 0.6911 | 1.7907 |
| Studi 6 | 2023 | 0.6105 | Medium effect | 0.2559 | 0.1089 | 1.1120 |
| Studi 7 | 2020 | 0.4583 | Simple effect | 0.2405 | -0.0131 | 0.9298 |
| Studi 8 | 2021 | 0.7122 | Medium effect | 0.3265 | 0.0723 | 1.3522 |
| Studi 9 | 2019 | 1.4288 | Strong effect | 0.2925 | 0.8554 | 2.0022 |
| Studi 11 | 2019 | 0.8031 | Medium effect | 0.2487 | 0.3156 | 1.2905 |
| Studi 12 | 2019 | 0.4337 | Simple effect | 0.2439 | -0.0443 | 0.9117 |
| Studi 13 | 2022 | 0.4874 | Simple effect | 0.3061 | -0.1126 | 1.0874 |

Based on Table 3, each study has varying effect sizes, with effect sizes ranging from 0.0500 to 1.4288. Through the interpretation of effect sizes according to Cohen's classification, there is information that three studies have strong effect sizes, which means that applying the PBL model in these three studies strongly influences students' ability to understand mathematical concepts. In addition, there are five studies with a medium effect size, which means that applying the PBL model in these five studies moderately influences students' ability to understand mathematical concepts. There are also three studies with simple effect sizes, which means that applying the PBL model in these studies has a modest influence on students' ability to understand mathematical concepts. 1 study with a weak effect size, which means that the application of the PBL model had a weak influence on students' ability to understand mathematical concepts.

The homogeneity test was carried out to determine the estimation model for calculating the combined effect size of all primary studies. The information in Table 4 is needed to conduct a homogeneity test.

**Table 4. Heterogeneity of Effect Size Distributions**

| **Heterogeneity** | | | | |
|---|---|---|---|---|
| **Chi$^2$** | **Df** | **P-Value** | **I-Squared** | $\boldsymbol{\sigma^2}$ |
| 20.25 | 11 | 0.04 | 45.7 | 0.0621 |

Based on the information listed in Table 4, it was found that the p-value < 0.05, indicating that the distribution of effect sizes of primary studies used in the meta-analysis was heterogeneous. Therefore, the estimation model used to calculate the combined effect size is a random effect model. Fail-Safe N (FSN) was used to detect publication bias, which in this study produced an FSN value of 376 from 12 studies. By using the formula $\frac{376}{5(K)+10}$, where $k$ is th number of tudies otenerved, tfivee vaue obtained is $\frac{376}{5(12)+10} = \frac{376}{70} = 5.371 > 1$ Thus, it can be concluded that the studies used in this meta-analysis have sufficient tolerance for publication bias (Tamur et al., 2020). Next, Table 5 presents the results of the primary study meta-analysis using fixed and random effects models.

**Table 5. Meta-Analysis Results Based on Estimation Models**

| **Models** | **N** | **Effect Size and Confidence Interval** | | | | **Test of null (2-Tail)** | |
|---|---|---|---|---|---|---|---|
| | | **Effect Size** | **SE** | **Lower** | **Upper** | **Z-Value** | **P-Value** |
| Fixed effect | 12 | 0.7495 | 0.1566 | 0.5929 | 0.9061 | 9.38 | 0.0001 |
| Random effect | 12 | 0.7552 | 0.2471 | 0.5081 | 1.0023 | 6.73 | 0.0001 |

Based on the results of the homogeneity test in the primary study, it was found that the distribution of study effect sizes was heterogeneous, so the analysis was carried out using a random effects model. In Table 6, the random effects model row has a p-value in the Z test. With a p-value <0.05, it can be concluded that overall, the use of the PBL model has a more significant influence on students' mathematical reasoning abilities than the conventional model. The meta-analysis results show that the combined effect size is 1.23, which, according to Cohen's classification, is included in the strong effect size category. Thus, the conclusion is that overall, the application of the PBL model strongly influences students' mathematical reasoning abilities. In addition, a combined effect size of 1.23 means that students' mean mathematical reasoning ability increased by 88% compared to the control group (Coe, 2002). Considering that the distribution of primary study effects is heterogeneous, an analysis of study characteristics needs to be conducted to identify factors that cause heterogeneity in students' mathematical reasoning abilities. The meta-analysis results for several characteristics are presented in Table 6.

The results of research conducted by Manapiah Anadiroh (2019) concluded that the ability to understand mathematical concepts of students who studied using the problem-based learning model was a suitable qualification, and the problem-based learning model influenced the ability to understand mathematical concepts. After knowing that the distribution of primary study effect sizes shows heterogeneity, the author will analyze study characteristics that influence heterogeneity in students' mathematical literacy abilities. The results of the meta-analysis of study characteristics, such as educational level, year of research, learning model, and sample size, are presented in Table 6.

**Table 6. Meta-Analysis Results for Each Character Study**

| **Characteristics Study** | **Category** | **n** | **Hedges'sg** | **P-Value** | **95% CI** | |
|---|---|---|---|---|---|---|
| | | | | | **Lower** | **Upper** |
| Jenjang Pendidikan | SMP | 7 | 0.96 | 0.11 | 0.62 | 1.29 |
| | SMA | 4 | 0.50 | 0.63 | 0.15 | 0.84 |
| | PT | 1 | 0.43 | 0.04 | - 0.04 | 0.91 |
| Wilayah | Pulau Jawa | 5 | 0.70 | 0.07 | 0.14 | 1.27 |
| | Luar Pulau Jawa | 7 | 0.79 | 0.07 | 0.44 | 1.13 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Tahun Penelitian | 2019-2020 | 8 | 0.83 | 0.04 | 0.44 | 1.23 |
| | 2021-2023 | 4 | 0.60 | 0.97 | 0.47 | 0.73 |

Based on the information in Table 6, it can be concluded that the level of education significantly influences a student's ability to understand mathematical concepts. This can be seen from the size of the effect each level of education has. The analysis results show that the lowest study effect size is at the tertiary level at 0.43, while the highest is at the junior high school level at 0.96. The lower and upper limit data also show that the PT level has a stronger effect than the middle and high school levels. Thus, learning does not significantly influence the ability to understand mathematical concepts at an educational level.

Based on the data in Table 6, it can be concluded that student's ability to understand mathematical concepts is influenced by the year of research. The analysis shows that all research years have a significant influence, with the effect size of each research year being in the medium category. Even though the highest study effect size was in 2019-2020 and the lowest was in 2021-2023, there is a wedge between the two periods' lower and upper limit intervals. Therefore, it can be concluded that there is no significant difference in the influence of learning on students' ability to understand mathematical concepts based on the year of research. Based on the data contained in Table 6, it can be concluded that students' mathematical concept abilities are influenced by the location used. The analysis shows that all research locations have a significant influence, but there are differences in the level of influence between the research locations. The lowest study effect size was found in locations on the island of Java, while the highest was outside Java. However, there was a wedge between the two periods' lower and upper limit intervals. Therefore, it can be concluded that there is no significant difference in the influence of learning on students' ability to understand mathematical concepts based on the year of research.

## 5. Conclusion

The results of a meta-analysis using 12 studies that investigated the effect of learning on students' ability to understand mathematical concepts found that the combined effect size of primary studies was 0.7552, which is included in the medium effect size category based on Cohen's classification. Thus, the conclusion is that the application of the Problem-Based Learning learning model as a whole does not have a moderate and significant influence on student's ability to understand mathematical concepts when compared with the application of conventional and other learning models.

Apart from that, from the analysis of several study characteristics, it was found that the influence of the PBL learning model on improving students' ability to understand mathematical concepts did not significantly influence educational level, year of research, and research location. These findings are essential for teachers in selecting and implementing the PBL learning model to improve students' ability to understand mathematical concepts according to their educational level. However, the author also suggests that this study can be studied further to gain a deeper understanding.

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