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Meta-Analysis: The Effect of Project-Based Learning toward Mathematical Concepts Understanding in Term of Learning Media Utilization

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Abstract. Various previous studies on the use of the Project-Based Learning (PjBL) model and its impact on mathematical concepts understanding provide varying reports. This research aims to evaluate the impact of the PjBL model on mathematical concepts understanding and investigate its effects based on the type of instructional media. The research method employed is quantitative with meta-analysis, intended to combine, evaluate, and integrate findings from several published studies. Data was collected through documentary studies by searching articles that published in national and international journals. 32 studies met the predefined inclusion and exclusion criteria. Data analysis was conducted using JASP software version 0.18.1.0. The research results indicate that the effect size of the PjBL model on mathematical concepts understanding is significant in the large category. Moreover, statistically, there is significant differences of effect size of the PjBL model depending on the type of learning media used. The implementation of the PjBL model shows a very large effect size on mathematical concepts understanding when using digital learning media and a large effect when using manual learning media. Meanwhile, without using learning media, the effect size of the PjBL model on mathematical concepts understanding is in the medium category.

Keywords: Effect Size; Mathematical Concepts Understanding; Mathematics Learning Media; Meta-Analysis; Project-Based Learning

Abstrak. Berbagai penelitian terdahulu tentang penggunaan model Project Based Learning (PjBL) dan dampaknya terhadap pemahaman konsep matematis memberikan laporan yang beragam. Penelitian ini bertujuan untuk mengevaluasi dampak penggunaan model PjBL terhadap pemahaman konsep matematis dan menyelidiki efeknya berdasarkan jenis media pembelajaran. Metode penelitian yang diterapkan bersifat kuantitatif dengan menggunakan meta-analisis, dimaksudkan untuk menggabungkan, mengevaluasi, dan mengintegrasikan temuan dari sejumlah studi yang telah dipublikasikan. Teknik pengumpulan data dilakukan melalui studi dokumentasi dengan melakukan penelusuran artikel yang dipublikasikan pada jurnal nasional dan internasional. 32 studi memenuhi kriteria inklusi dan eksklusi yang telah ditetapkan. Analisis data dilakukan menggunakan perangkat lunak JASP versi 0.18.1.0. Hasil penelitian menunjukkan bahwa ukuran efek dari model PjBL terhadap pemahaman konsep matematika secara signifikan berada dalam kategori besar. Selain itu, secara statistik, terdapat perbedaan yang signifikan dalam ukuran efek model PjBL tergantung pada jenis media pembelajaran yang digunakan. Penerapan model PjBL menunjukkan ukuran efek sangat besar terhadap pemahaman konsep matematika ketika menggunakan media pembelajaran digital, dan efek besar ketika menggunakan media pembelajaran manual. Sementara itu, tanpa penggunaan media pembelajaran, ukuran efek model PjBL terhadap pemahaman konsep matematika berada dalam kategori sedang.

Kata kunci: Media Pembelajaran Matematika; Meta-Analisis; Pemahaman Konsep Matematika; Pembelajaran Berbasis Proyek; Ukuran Dampak

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INTRODUCTION

Mathematical understanding is outlined by Polya in four stages. The first stage is *mechanical understanding*, which characterized by the ability to memorize and apply formulas routinely and perform simple calculations. The second stage is *inductive understanding*, which involves applying formulas or concepts in simple or similar cases. Next, the third stage is *rational understanding*, where one is expected to prove the truth of a formula and theorem. Finally, the fourth stage is *intuitive understanding*, which involves the ability to estimate the truth with full confidence, without doubt (Syarifah et al., 2021). Understanding refers to ideas or concepts that can be broken down or understood by students, so they can comprehend its meaning, find ways to express that idea, and explore related possibilities (Parhusip & Hardini, 2020). In the context of mathematics, mathematical understanding is closely related to understanding concepts, its connection to mathematical facts and methods, including those that may be hidden, in the context of solving mathematical problems. Students with a good level of mathematical understanding will be able to solve problems effectively and correctly (Fasaenjori et al., 2023)

Some research report that mathematical understanding is significantly correlated at 42.25% with problem-solving skills (Wulandari & Darminto, 2016). Furthermore, mathematical understanding has a linear correlation with other mathematical abilities, such as mathematical connection abilities (Fasaenjori et al., 2023). The level of students' mathematical understanding can be measured on various evaluation occasions, one of which is through international assessments like PISA. Based on the PISA 2022 report, Indonesian students achieved an average score of 366 in mathematics, placing them in the Level 1 category (OECD, 2023). This indicates a decline compared to the PISA 2018 average score of 379. PISA 2022 reports that only 18% of Indonesian students reached Level 2, meaning they can independently interpret and recognize how simple situations can be represented mathematically, such as comparing the total distance between two alternative routes or converting prices into different currencies. Data on the average scores of PISA 2022 in mathematics for ASEAN countries can be found in Table 1.

Table 1. Indonesian Mathematics Scores among ASEAN Countries in PISA 2022

No	Country	Average Score
1.	Singapura	575
2.	Vietnam	469
3.	Brunei Darussalam	442
4.	Malaysia	409
5.	Thailand	394
6.	Indonesia	366
7.	Filipina	355
	Average of ASEAN	430

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Through the PISA results report, efforts should be made to improve the low mathematical competence. Students' understanding of mathematics is greatly influenced by the interaction and collaboration between teachers and students. Teachers need to present effective and engaging learning, actively involving students in the construction of their knowledge. This is in line with Through the selection of the right learning model will assist students in understanding the material with the aim that the material can be internalized as a concept, thus impacting the improvement of conceptual understanding (Pratama et al, 2020). Among the efforts that can be undertaken in improving mathematical understanding is through Project-Based Learning (PjBL) (Linda, 2015). Through the PjBL approach, students are given interesting projects that integrate various skills in the context of mathematical learning.

Learning through PjBL to enhance students' mathematical abilities has been extensively studied before. In her study, Linda (2015) reported that students who received PjBL showed better improvement in mathematical understanding compared to students who underwent expository learning. In a different study, Pratama et al. (2020) also reported that learning with PjBL can enhance students' mathematical understanding. Significant improvement in mathematical understanding through the implementation of the PjBL model is also reported in other studies (Amalafitra et al., 2023; Carter, 2016; Fatahillah & Faradillah, 2023; Febryana & Nugraheni, 2023; Hartono, 2018; Inpinit & Inprasit, 2016; Kosmani et al., 2023; Nurbavliyev et al., 2020). However, in some other studies, there are reports of less or insignificant results, as reported in other studies (Fiana et al., 2019; Herawati et al., 2021; Jazuli et al., 2019; Nopiani & Julianingsih, 2023).

In addition to the implementation of the PjBL model in mathematics education, the use of media is also a factor in improving mathematical understanding. Similarly, it was reported in a study (Hussein et al., 2022) that instructional media, including Self-Access Center (SAC) media, can be used to explore students' mathematical understanding. The use of instructional media becomes a means to help teachers deliver material in a planned, engaging, and stimulating manner, encouraging students to enhance understanding (Fasaenjori et al., 2023). Thus, it is expected that learning objectives can be achieved more effectively. Furthermore, the success of media utilization in the learning process can be achieved through synergy among teachers, students, and schools (Lestari et al., 2022). It is important to create shared awareness that the role of media is very significant in creating engaging learning.

The utilization of both digital and manual instructional media, along with the implementation of the PjBL model, has been reported to enhance students' mathematical understanding (Amalafitra et al., 2023; Fatahillah & Faradillah, 2023; Inpinit & Inprasit, 2016; Kosmani et al., 2023). However, the implementation of PjBL without the use of instructional media has also been reported to improve mathematical understanding. However, there are also study findings indicating that the

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use of PjBL without utilizing instructional media does not significantly enhance students' mathematical understanding.

The meta-analysis method becomes an effective choice to gather and integrate findings from previous studies, thus producing stronger and more reliable conclusions regarding PjBL model and mathematical concepts understanding. It is essential to merge the findings of previous research on PjBL in improving mathematical understanding to formulate aggregate conclusions (Retnawati et al., 2018). Merging the findings of previous research on PjBL in improving mathematical understanding is crucial for several reasons. *Establishing a comprehensive understanding*, by synthesizing the results of multiple studies, researchers can gain a more comprehensive understanding of the effectiveness of PjBL in enhancing mathematical understanding. Individual studies may have limitations or focus on specific aspects, but by combining their findings, researchers can paint a clearer picture of the overall impact of PjBL. *Identifying patterns and trends*, aggregating research findings allows researchers to identify patterns and trends across different studies. They can discern commonalities in the outcomes, methodologies, or contexts, which can provide insights into the factors that contribute to the success or challenges of implementing PjBL in mathematics education. *Enhancing generalizability, e*ach study on PjBL in mathematics education may be conducted in a specific context, such as a particular grade level, demographic group, or geographic location. By merging findings, researchers can assess the generalizability of the results across diverse settings, thereby strengthening the validity and applicability of the conclusions. *Validating results*, replication is a fundamental principle of scientific inquiry. When multiple studies produce consistent findings regarding the effectiveness of PjBL in improving mathematical understanding, it lends credibility to the results. Conversely, discrepancies or conflicting findings among studies may signal areas that require further investigation or clarification. *Informing practice and policy,* policymakers, educators, and curriculum developers rely on research evidence to make informed decisions about educational practices and policies. Aggregating research findings on PjBL in mathematics education provides stakeholders with a robust evidence base to guide their decision-making processes, facilitating the implementation of effective instructional strategies in real-world educational settings. And *advancing theory,* synthesizing research findings can contribute to the advancement of theoretical frameworks in mathematics education and PjBL. By identifying gaps, contradictions, or areas requiring further exploration, researchers can generate new hypotheses, refine existing theories, and stimulate further research inquiry in the field.

Overall, merging the findings of previous research on PjBL in improving mathematical understanding is essential for advancing knowledge, informing practice, and ultimately enhancing student learning outcomes in mathematics education. Meta-analysis plays a crucial role in research,

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especially in the field of education. Several reasons emphasizing the importance of meta-analysis, according to Hunter, include overcoming weaknesses in primary research, such as limited sample size or inconsistent results (Hansen et al., 2022). Bushman & Wells, in their approach, state that meta-analysis provides the ability to manage a large number of studies more efficiently and ensures that the conclusions drawn can be replicated more consistently (Crocetti, 2016). Another urgency of meta-analysis is to enhance the validity and reliability of research results through more comprehensive hypothesis testing and provide stronger evidence of the relationship between variables (Retnawati et al., 2018). The urgency arises from the need to gain deeper insights into the combined effects of PjBL and learning media on mathematical understanding. By conducting a meta-analysis, researchers can systematically analyze a large body of research to identify patterns, trends, and best practices. This comprehensive approach helps to strengthen the evidence base and inform educational policies and practices. This research endeavor is crucial for advancing our understanding of how innovative teaching approaches and educational technologies can enhance students' learning outcomes in mathematics.

Meta-analysis studies related to PjBL have been extensively conducted, including meta-analyses on PjBL's impact on mathematical creative thinking skills (Damanik et al., 2021; Yunita et al., 2021). Some researchs reported the results of a meta-analysis on PjBL's impact on problem-solving skills in 15 articles spanning from 2019 to 2021 (Laraswati et al., 2023). Additionally, meta-analysis studies on PjBL's impact on mathematical abilities have also been conducted (Sihombing & Susilowaty, 2023; Syarifah et al., 2021) covering various mathematical abilities such as mathematical understanding, critical thinking, mathematical connections, creative thinking, mathematical communication, and problem-solving from 2015 to 2021 and 2015 to 2022. Specifically, a meta-analysis study on the impact of PjBL on mathematical concepts understanding has been conducted in the field of science (Novebrini et al., 2021) As for mathematics education, a meta-analysis study on the influence of contextual learning on mathematical conceptual understanding has been conducted (Parhusip & Hardini, 2020). The novelty of this research lies in examining the impact of PjBL on mathematical concepts understanding by detailing studies published in prestigious journals indexed in DOAJ, Crossref, Shinta, or Scopus from 2015 to 2023. This study encompasses 32 research papers with subjects from both within and outside Indonesia. Additionally, a review is conducted on the use of instructional media in this context.

METHOD

This research employs a quantitative approach, which is a positivist theory-based approach (Lestari & Yudhanegara, 2017). Quantitative research involves a group of methods for testing theories by observing relationships between variables Creswell (2018). This study uses the correlation meta-analysis research type, an examination that combines relevant study results (Sriawan & Utami,

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2015). Meta-analysis is a statistical approach that integrates information from at least two studies investigating relationships through relational, experimental, or semi-experimental studies. Meta-analysis is objective, focusing on data rather than research conclusions, by combining and analyzing data using quantitative techniques to derive more accurate conclusions (Rosdiana, 2021).

Correlation meta-analysis, as explained by Retnawati et al. (2018), begins by establishing the effect size. Next, this effect size is transformed using the z-transformation (Fisher's transformation). The transformed effect size is then used to calculate the summary effect and test heterogeneity in the random-effects model. The summary effect results, through both FE and RE models, are then converted back to correlation coefficients (r). Subsequently, the interpretation and reporting of the meta-analysis study results are conducted. This meta-analysis method includes a systematic review and descriptive analysis examining published studies related to project-based learning and mathematical concepts understanding.

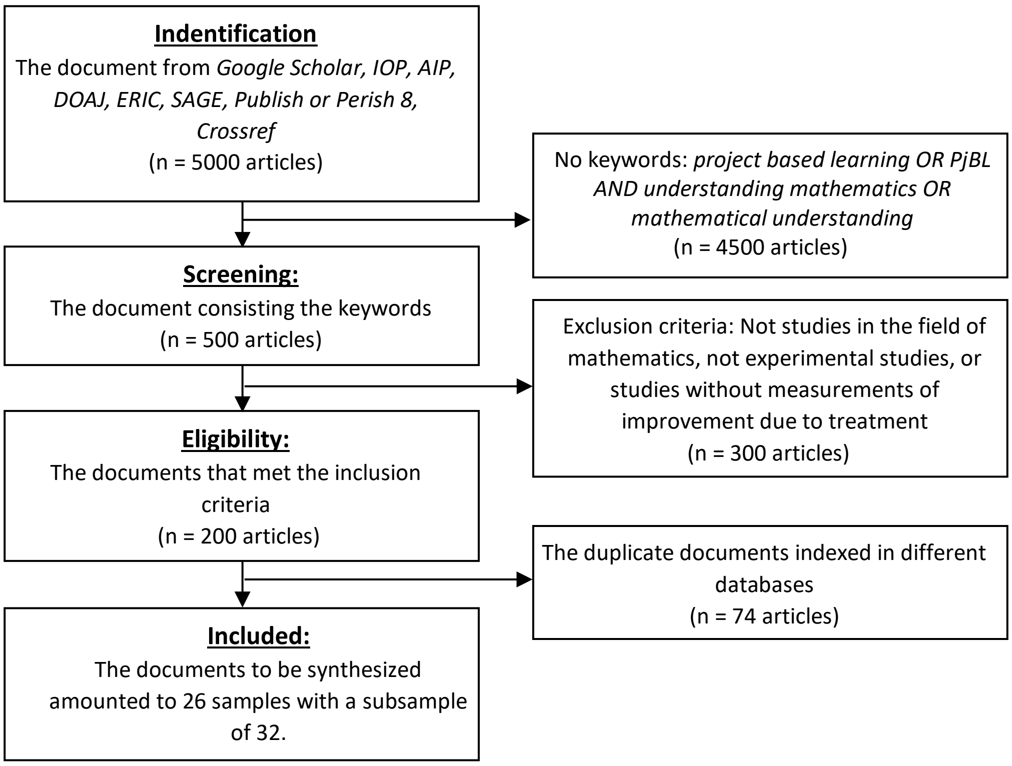

Figure 1. Flowchart of Studies Search Results

The data collection method in this study uses documentary research. Documentation refers to a technique used to obtain information in the form of documents such as writings, images, and other significant works (Sugiyono, 2022). In this study, documentation includes students' learning outcomes indicating mathematical concepts understandin, taken from published articles. The data resulting from the study search in the database is then presented in Figure 1, which includes information about the location and duration of the research as well as a description of the validity checking of the examined research results.

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To collect data for synthesis in the meta-analysis, the researcher searched for articles or studies using keywords such as "project-based learning," "mathematical understanding," and "mathematical understanding" through the Publish or Perish 8 application, DOAJ, Crossref, and Google Scholar, focusing on journals indexed in the Science and Technology Index (SINTA). Afterward, the researcher sorted through articles to select those that met the predetermined inclusion and exclusion criteria. From the sorting results of over 5000 articles, 32 studies were obtained for synthesis in this research. The distribution of indexing articles as on Figure 2.

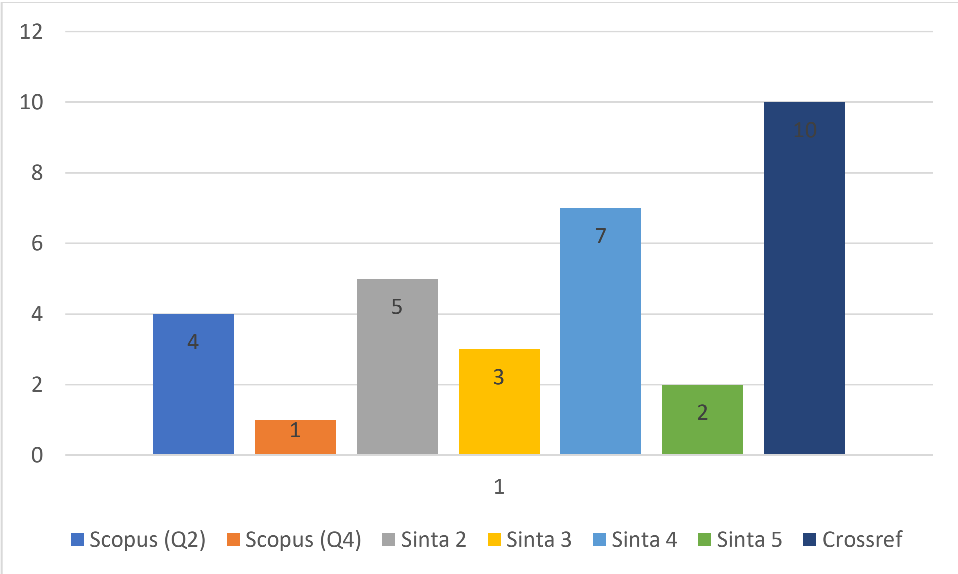

Figure 2. The Distribution of Articles Indexing

The instrument that used in this study is a modified coding sheet from Laraswati et al. (2023) including information such as the researcher's name, research title, publication year, research location, journal access time, journal index, sample size, research design, education level, instructional media used, dependent variable (mathematical concepts understanding), sampling technique, statistical test value, research hypothesis, research results or findings, and journal URL address. The population in this study is research journals, theses, proceedings, and articles related to PjBL in mathematics education. The sampling was done using purposive sampling technique, selecting studies from the population that met the inclusion and exclusion criteria. The purpose of using purposive sampling in a study on PjBL in improving mathematical understanding is to strategically select participants or cases that best serve the research goals, ensuring that the data collected is meaningful, relevant, and aligned with the research objectives. The inclusion criteria of literature in this study were: the publication years of the research range from 2015 to 2023, the languages used are Indonesian and English, the types of publications include articles and conference proceedings in mathematics education, the articles are indexed in Crossref, DOAJ, Scopus, Sinta (Kemenristekdikti), and are openly accessible. The exclusion criteria in this research are not studies on mathematics learning with PjBL and mathematical understanding, no

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experimental/quasi-experimental research methods, and not containing essential data to calculate effect sizes it includes statistical values such as mean, standard deviation, sample size, and statistical test value (t or F test); and the article not includes the influence of PjBL on mathematical concepts understanding.

This research applies correlation meta-analysis, which is divided into two main components: calculating the effect size in each study and the summary effect size that encompasses all studies. Besides these two aspects, heterogeneity testing is also performed in the correlation meta-analysis process. The effect size calculation for each study uses Cohen's equation (Retnawati et al., 2018) which is then categorized according to Cohen's interpretation (Yunita et al., 2021) and can be presented in Table 2.

Table 2. The Effect Size Categories in Cohen's Interpretation

No	Effect Size	Interpretation
1	0.00 – 0.19	Ignored
2	0.20 – 0.49	Small
3	0.50 – 0.79	Medium
4	0.80 – 1.29	Large
5	1.30 and more	Very Large

In the framework of this meta-analysis research, there are two hypotheses to be tested. First, the hypothesis evaluates the effect size from all synthesized studies and whether this effect size is significant. The second hypothesis involves testing heterogeneity, aiming to determine whether the effect size from each study synthesized in this research is heterogeneous or homogeneous. The calculations for the summary effect size and Forest plot will be conducted using the JASP 0.18.1.0 software. The JASP application is freely accessible and can be used without charge as it is open source. This aligns with the information released on its application interface, which promotes the slogan "free, friendly, and flexible."

RESULTS AND DISCUSSION

Selecting only 32 articles out of a pool of 5000 for a study might seem like a small sample size, but it's essential to consider the quality and relevance of the articles rather than just the quantity. Researchers typically use rigorous criteria to select articles that are most pertinent to their research questions, ensuring that the sample represents a diverse range of perspectives, methodologies, and findings within the literature. Regarding the distribution of media types (manual vs. digital) among the selected articles, it's crucial to remember that the sample size is relatively small, so fluctuations in the distribution of variables like media type can occur.

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In this case, the fact that manual media has only 2 articles and digital media has 12 does not necessarily indicate that one type of media is more prevalent or significant than the other in broader literature. It could be a result of chance variation within the sample. While the sample size of 32 articles may appear small, its representativeness depends on the rigor of the selection process, the coverage of the literature, the presence of bias, and the generalizability of the findings. Researchers should carefully evaluate these factors to determine the extent to which the sample accurately reflects the existing problem and contributes to the advancement of knowledge in the field. The results of the effect size calculations for each study out of the 32 studies are presented in the following Table 3.

Table 3. The Results of Effect Size Calculations for Each Synthesized Studies

Studies	Effect Size	Standart Error Effect Size	Learning Media
S1	1.110352	0.130188911	Manual
S2	1.276613	0.124034735	Manual
S3	-0.17154	0.21821789	Without Media
S4	1.012376	0.229415734	Without Media
S5	-0.54621	0.12803688	Without Media
S6	1.787519	0.185695338	Without Media
S7	0.696593	0.171498585	Without Media
S8	0.574121	0.150755672	Digital
S9	1.501372	0.176776695	Without Media
S10	1.216461	0.141421356	Without Media
S11	2.425362	0.19245009	Without Media
S12	0.102744	0.150755672	Without Media
S13	1.846573	0.147441956	Digital
S14	0.681227	0.125988158	Without Media
S15	2.125309	0.09166985	Without Media
S16	1.460717	0.122169444	Digital
S17	0.55902	0.122169444	Without Media
S18	0.82119	0.149071198	Without Media
S19	0.008279	0.083333333	Without Media
S20	-0.09898	0.132453236	Without Media
S21	-1.42194	0.19245009	Without Media
S22	0.754352	0.086386843	Digital
S23	0.590962	0.086386843	Digital
S24	0.402594	0.086386843	Digital
S25	0.093333	0.134839972	Without Media
S26	0.114974	0.094072087	Without Media
S27	1.670101	0.122169444	Without Media
S28	1.088729	0.147441956	Digital
S29	2.851376	0.2	Digital
S30	-0.36181	0.138675049	Without Media

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Studies	Effect Size	Standart Error Effect Size	Learning Media
S31	3.150262	0.15430335	Digital
S32	1.275608	0.149071198	Without Media

Based on Table 3, it is found that 15.625% of the studies do not have a significant effect, namely S3, S5, S20, S21, and S30. Effects categorized as ignored occur in 12.5% of the studies, namely S12, S19, S25, and S26. Only S24 has an effect categorized as small. Additionally, studies with effects categorized as medium constitute 18.75%, including S7, S8, S14, S17, S22, and S23. About 21.875% of the studies have effects categorized as large, namely S1, S2, S4, S10, S18, S28, and S32. Furthermore, 28.125% of the studies with effects categorized as very large include S6, S9, S11, S13, S15, S16, S27, S29, and S31.

Referring to Table 3, a heterogeneity test is then conducted to determine if there are differences in the effect size of each study. Heterogeneity testing can be done using three methods, as explained by Retnawati et al. (2018), by using the Q-value, tau-square, and I2. The null hypothesis (H_0) posits that the true effect is the same, while the alternative hypothesis (H_a) suggests that the effect size between studies is different (heterogeneous). The calculation results using the random-effect model at a 95% significance level are shown in Table 4.

Table 4. Heterogenity Test by Parameter Q

Fixed and Random Effects			
	Q	**df**	**p**
Omnibus test of Model Coefficients	25.977	1	< .001
Test of Residual Heterogeneity	1442.687	31	< .001

Note. p -values are approximate.
Note. The model was estimated using Restricted ML method.

Based on Table 4, the Q parameter value is obtained as 1442.687, with Q being the weighted sum square (WSS) or the sum of weighted squares. The p-value for Q is less than 0.001, which means it is less than alpha (0.05), thus concluding that the variation between studies is statistically significant. In other words, the effect size from each synthesized study is heterogeneous. Similarly, using tau square and I^2 through the JASP application, the results are presented in Table 5.

Table 5. Heterogenity Test by Parameter *Tau Square* dan I^2

Residual Heterogeneity Estimates			
		95% Confidence Interval	
	Estimate	**Lower**	**Upper**
τ^2	0.959	0.610	1.725
T	0.979	0.781	1.313
I^2 (%)	98.314	97.375	99.055
H^2	59.295	38.092	105.871

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Referring to Table 5, it is obtained that tau square = 0.959 > 0; hence, the null hypothesis (H^0) is rejected, meaning the effect size of each synthesized study is heterogeneous. The I^2 value is 98.314%, approaching 100%. According to Retnawati et al. (2018), a good I^2 value is close to 100%. Therefore, based on the tau square and I^2 parameters, the conclusion is drawn that the effect size of each study in this research is heterogeneous.

Considering the results of the heterogeneity tests, both with the Q parameter and the tau square and I^2 parameters, indicating that statistically, all studies are different or heterogeneous, the overall summary effect size of PjBL on mathematical understanding is determined using the random-effect model. The JASP application provides the summary effect size, as presented in Table 6.

Table 6. Estimation of Summary Effect Size

Coefficients						
					95% Confidence Interval	
	Estimate	**Standard Error**	**z**	**P**	**Lower**	**Upper**
Intercept	0.892	0.175	5.097	< .001	0.549	1.235

Note. Wald test.

Based on Table 6, it is shown that the overall average effect size of the PjBL model on mathematical understanding is 0.892, indicating a large effect according to Cohen's classification. The table also indicates a p-value < 0.001, which is less than the alpha value (0.05), leading to the conclusion that there is a significant effect of the PjBL model on mathematical understanding. In addition to the summary effect size estimation, the JASP application also provides a forest plot, presented in Figure 3.

In the context of meta-analysis research, it is essential to investigate publication bias because articles that achieve statistical significance are often more likely to be published (Rahmawati et al., 2022). Researchers tend to publish studies that show statistical significance (around 6%), while studies that do not achieve statistical significance are less likely to be reported (Cooper et al., 2019). Several methods can be used to investigate publication bias in meta-analysis research, involving the use of a funnel plot, the results of the rank regression test for funnel plot, the results of the Egger Test, and the calculation of the Fail-Safe N value. The following is a presentation of the funnel plot in Figure 4.

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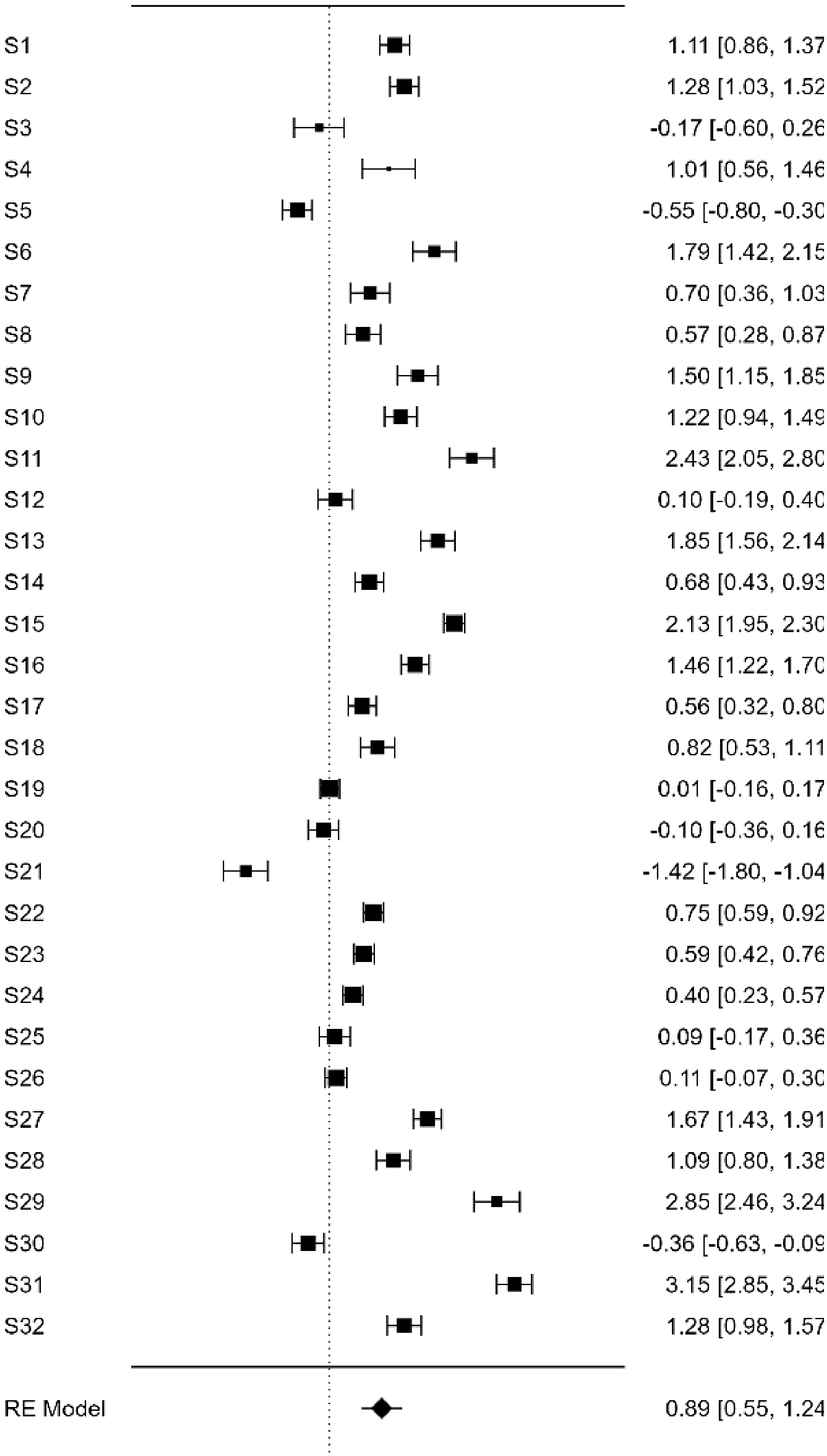

Figure 3. Forest Plot of All Studies

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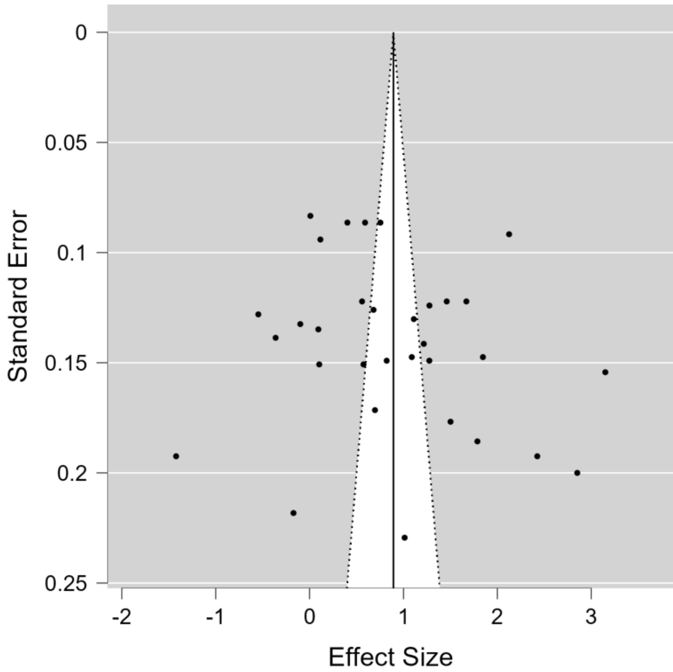

Figure 4. Funnel Plot of All Studies

The results from the Funnel plot diagram can be used as an indicator to assess the likelihood of publication bias in the research. This evaluation is conducted by assessing whether the shape of the Funnel plot diagram shows symmetry or asymmetry. Based on Figure 4 of the Funnel plot diagram, it is challenging to conclude whether the diagram exhibits symmetry or not. Therefore, the use of the Rank Correlation and Regression Method is required to test whether the Funnel plot diagram shows symmetry or not. The results of both statistical tests can be found in Table 7.

Table 7. Result Rank Correlation Test dan Egger Reggression Test

Test Name	**Test Result**	**P-Value**
Rank Correlation Test	Kendall's Tau 0.163	0.194
Egger Reggression Test	z 0.832	0.405

Next, the Fail-Safe N test was conducted, and in this meta-analysis research, the Fail-Safe N value obtained is 15,501. Based on the results of the Rank Correlation Test and Egger Regression Test in Table 7, the p-value is greater than the alpha value (0.05), and the Fail-Safe N value is greater than 5k+10 (5.32 + 10 = 170). Therefore, it is concluded that the studies synthesized in this research are free from publication bias. Subsequently, a statistical analysis of the summary effect size concerning the use of learning media is presented in Table 8.

Table 8. The Analysis Results of PjBL on Mathematical Concepts Understanding in Term the Use of Learning Media

Use of Learning Media	**Number of Study (n)**	***Summary Effect Size***	**Effect Category**	***Qb (Varians Between)***	***df***	***p-Value***
Media Manual	2	1.198	Large	92.478	2	8.291×10^{-21}
Media Digital	9	1.406	Very Large			
Without Media	21	0.642	Medium			

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Based on Table 8, the Qb value obtained is 92.478 > Q Table = 5.99, and the p-value obtained is 8.291x10-21 < alpha (0.05), meaning that there is a significant difference in the PjBL model's impact on mathematical understanding when viewed from the use of learning media. The number of studies included in the meta-analysis does not significantly influence the magnitude of the summary effect size obtained. This finding is consistent with the results of meta-analysis studies conducted by Alfonsus et al. (2015), Izzah & Mulyana (2021), and Syarifah et al. (2021).

This research employs a meta-analysis method with the aim of analyzing the application of the PjBL model on students' mathematical understanding. Through a search using Publish or Perish 8 on databases like Crossref, Google Scholar, DOAJ, and indexed SINTA and Scopus journals, more than 5000 articles were obtained. After extraction based on predefined inclusion and exclusion criteria, 32 relevant studies were selected for further analysis in this research. Following the analysis phase using JASP version 0.18.1.0, the results will be quantitatively presented.

Based on the conducted heterogeneity test, it is concluded that the true effect in the analyzed studies differs, or in other words, these studies are heterogeneous. Therefore, it is advisable not to use a fixed-effect model for drawing conclusions. Instead, the more appropriate statistical model for this meta-analysis research is the random-effect model. Based on the summary effect size analysis using JASP with a random-effect model, an effect size of 0.892 is obtained, categorized as a large effect on the use of the PjBL model regarding students' mathematical understanding. This finding aligns with research by Sihombing & Susilowaty (2023) that PjBL significantly influences mathematical understanding. Similarly, a meta-analysis study by Novebrini et al. (2021) in the field of science indicates that the PjBL model can enhance students' conceptual understanding. PjBL significantly contributes to the improvement of mathematical understanding because students are actively engaged in the learning process, facing various complex issues relevant to daily life (Linda, 2015). In PjBL, students actively participate in discussions, work, and present their findings (Herawati et al., 2021).

Considering the use of learning media, Table 8 reveals that there is a significant difference in effect size concerning the application of the PjBL model on mathematical understanding. The analysis of studies concerning the utilization of learning media indicates that in all media usage contexts, whether digital, manual, or without learning media, a significant summary effect size is found. Specifically, a very large effect is observed when using digital media (1.406), a large effect with manual media (1.198), and a medium effect without the use of learning media (0.642). Thus, it can be concluded that whether using learning media or not, the PjBL model still affects students' mathematical understanding. Syarifah et al. (2021) state that utilizing learning media is key to improving efficiency and providing practical mathematical concept understanding. Research involving digital media, especially interactive media, as reported Lusiana et al. (2019), has a significant impact on mathematical abilities. However, the results of a meta-analysis study on science learning conducted by Novebrini et al. (2021) indicate that the use of manual media has a high impact, while digital media provides a medium impact. Nevertheless, overall, Novebrini et al. (2021) conclude that the use of learning media in the PjBL model is effective in improving students' conceptual understanding.

CONCLUSION

Based on the analysis of the summary effect size using JASP with the random-effect model, an effect size of 0.892 was found, categorized as a large effect. This finding is consistent with previous research indicating that PjBL has a positive impact on students' mathematical understanding. In the context of learning media utilization, the analysis indicates a significant difference in effect size in the implementation of PjBL on mathematical understanding, whether with digital media, manual media, or without learning media. This result emphasizes that PjBL continues to have a positive impact, whether with or without the support of learning media. The conclusions drawn from this meta-analysis align with the research questions posed. First, the analysis confirms a significant effect size across all synthesized studies, indicating a large effect of PjBL on students' mathematical understanding. Secondly, the examination of heterogeneity suggests varied effect sizes among the studies, emphasizing the need to consider factors contributing to this diversity. The finding of a large effect size supports previous research indicating the positive impact of PjBL on mathematical understanding. Moreover, the analysis underscores the significance of PjBL regardless of the utilization of learning media, whether digital, manual, or none, indicating its consistent positive influence. In the context of mathematics education, particularly in enhancing mathematical understanding, the study suggests further optimization of learning media development, especially digital platforms.

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