Psychology, Evaluation, and Technology in Educational Research
8 (2), 2026, 107-124

Available Online: http://petier.org/index.php/PETIER

Project-based learning in vocational schools: A meta-analysis study

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Received: 14 November 2025; Revised: 30 March 2026; Accepted: 6 April 2026

Abstract: Project-Based Learning (PBL) have shown significant results in increasing students' mathematical skill. In a meta-analysis involving 17 studies, the results show that PBL significantly increases the students' mathematical skills. The results of the fixed and random effects analysis show that the overall coefficient model and the residual heterogeneity are significant. The coefficient estimation for the intercept within the model is 71.872, which shows that when all independent variables are worth to zero, the dependent variable is worth estimated to 71.872. A very small p-value (< 0.001) indicates that the results are statistically very significant. The models have a good fit with the observational data, but it could not explain the variation between studies. There is a high level of heterogeneity among studies and there is not any indication of publication bias in the analysis. Thus, the results show that PBL basically can increase the students' mathematical skills. However, it is necessary to consider other factors that can influence the results.

Keywords: Project-Based Learning, Meta-Analysis, JASP, High School

How to Cite: Astuti, N. D., Prihatni, Y., Setiawan, A., Retnawati, H., Setiawan, R., Surwanti, D., & Supriyanto, J. (2026). Project-based learning in vocational schools: A meta-analysis study. *Psychology, Evaluation, and Technology in Educational Research*, *8*(2). https://doi.org/10.33292/petier.v8i2.299

INTRODUCTION

The integration of science and technology in education emphasizes on the innovation and the use of learning technology (Surry, 2008). Educational technology is considered as a tool to improve the quality of learning both inside and outside the class. This is especially important in IT specialist training, where STEM education is essential for developing competencies (Shchyrba et al., 2022). Implementing the Technology Readiness Acceptance Model in education is considered as a strategy to maximize the benefits of technology in teaching and learning (Nafia et al., 2023; Maritsa et al., 2021)

Traditional education, characterized by a top-down and teacher-centered approach, is slowly being replaced by student-centered and collaborative learning strategies (Wang, 2022). Research supports this transition, showing that student-centered methods such as project-based learning can improve learning outcomes and cognitive skills (Hafeez, 2021). However, it is still important for educators to use a variety of teaching methods that encourage active learning (Levitt & Grubaugh, 2023).

Education is currently experiencing a shift from a passive to an active learning approach. Project-based learning places students as active subjects in the learning process, giving them the opportunity to learn through real experience and the application of mathematical concepts in practical situations (Arnold, 2022; Craig et al., 2020; Ismawati et al., 2018). Vocational schools play an important role in preparing students to enter the working world, and teachers play an important role in facilitating practical learning (Mariah & Sari, 2019). The quality of vocational education is also important, with a focus on the competence of teaching staff, curriculum and available facilities (Henny & Tambingon, 2022). Xiao-ling, (2010) emphasizes the importance of students participating in the assessment of their employability skills to improve their employability. Besides that, (Soika, 2014) Soika (2014)highlights the importance of career management competencies in vocational schools, which assist students in understanding themselves, setting their career goals, and navigating the labor market. Through a project-based learning approach, students in vocational schools can develop practical skills while deepening their understanding of mathematical concepts relevant to their chosen profession (Ahmad et al., 2023; Usmeldi & Amini, 2022).

One of the challenges in learning mathematics is connecting theoretical concepts with practical applications in daily life. By incorporating mathematics into real projects in vocational schools, students can see the relevance and usefulness of mathematics in various contexts, motivating them to study this subject more seriously (Lumbantoruan, 2023; Noto et al., 2019). Project-based learning allows students to be actively involved in learning, increasing their motivation and interest in mathematics learning. By paying attention to contexts that are concrete and relevant to them, students are more likely to engage deeply in the learning process (Kamil et al., 2023; Kesumawati et al., 2023). Math and problem-solving skills are essential in many areas of workfield. Through a project-based learning approach in vocational schools, students can develop these skills contextually, so that they are ready to face challenges in the working world (Hidayatullah et al., 2020; Youyou & Kit, 2024).

Sometimes, previous research covering similar topics produced different findings, making it difficult to reach objective conclusions. Therefore, a meta-analysis study is needed. Meta-analysis research is considered a quantitative approach that uses effect sizes from various relevant studies to provide comprehensive and in-depth conclusions regarding the power effects, correlations, and relationships between variables (Agussuryani et al., 2022; Russo & Russo, 2007; Sumarni et al., 2020). Typically, these studies calculate average effect sizes, test for homogeneity and publication bias, and detect heterogeneity using moderator variables (Anwas et al., 2025; Arlinwibowo et al., 2022). However, to date, there is still little meta-analysis research that evaluates the effect of project-based learning models on students' mathematical abilities. In fact, mathematical skills and project-based learning are very important in the Industrial Revolution 4.0 era, especially to achieve the target of quality education. Therefore, teachers need to implement project-based learning to improve students' mathematical skills.

This research would analyze the effectiveness of project-based learning on problem-solving abilities using four moderator variables: sample size, gender, research area, and year of publication. The results of previous research showed that there is a significant difference between the learning outcomes of groups that used Information and Communication Technology (ICT) and groups that did not use it. Students who used ICT in learning showed better results. Data from Forrest plot shows a summary effect of 1.13, which means that learning outcomes with ICT are 113% higher compared to conventional learning. The 95% confidence interval shows an effect range between 0.83 to 1.44, indicating a significant difference without containing zero score (Arlinwibowo et al., 2022).

Based on the differences in results from previous research, this research aimed to expand and complement previous meta-analyses by focusing on project-based learning to improve students' mathematical skills as the dependent variable. This research would also see whether different dependent variables have a positive influence on the selected moderator variables (sample size, gender, research area, and year of publication).

The purpose of this meta-analysis is to synthesize project-based learning to improve students' mathematical skills. In the project-based learning model, students do not only listen, take notes, and memorize materials, but also actively think at a high level with competency in reasoning, communicating, and working together to reach a conclusion. This process indirectly stimulates students to improve their mathematical skills.

METHODS

This research used the IOP ScienceDirect electronic database, with the keywords "project-based learning", "vocational school", "mathematics", and "mathematics listening". From this search, 160 studies were found which were then filtered based on the inclusion criteria set by the researchers.

Criteria Inclusion in Meta-Analysis

Criteria inclusion in Meta-Analysis consists of (a) Range of years published from 2014 to 2023; (b) International research area; (c) Main studies which are published in SCOPUS indexed international journals via https://www.sciencedirect.com/; (d) Main studies using average effect sizes and selected moderator variables (sample size, research area, and year of publication); (e) Preliminary studies report sufficient data for calculating the magnitude of the impact.

After screening 160 previous studies, 17 main studies were chosen as data sources for meta-analysis. Of these 17 studies, eleven studies were conducted on the European continent. Seven out of the eleven studies were mainly conducted in Germany. All these 17 studies evaluated the influence of Project-BasedLearning on mathematical skill. Therefore, the studies from these 17 analyses are included in the meta-analysis.

Inclusion Criteria

The studies spans multiple continents: Europe, Asia, America and Africa. However, there is only one study from the African continent, which is from Tanzania. Meanwhile,most studies were originated from the European continent. This allows evaluation of whether or not project-based learning allows students to improve their varying mathematical skills across educational categories.

Coding and Selection of Moderator Variables

The moderator variables in this study are the sample size, research area, and year of publication. Year of publication: the publication of articles every year related to Project Based Learning on students' mathematical skills increases, especially in the last eight years. The year of publication was grouped into two categories: 2014-2019 and 2020-2023. Sample ze: the chosen sample size variable for analyzing different results was based on sample size of two categories: ≤ 500 and > 500.

Analysis

A meta-analysis of digital therapeutics studies found moderate to large effect sizes (Seo et al., 2024). Likewise, medication adherence interventions in older adults with chronic diseases were found to have a moderate impact (Jeon et al., 2022). Cognitive behavioral treatment of alcohol and drug users produces small but significant effects (Magill & Ray, 2009). The Hedges' g formula was used in all studies for measuring the effect size.

In this meta-analysis the effect size of each study was calculated using Hedges' g formula using JASP 0.18.3.0 Retnawati et al. (2018) software. Kanters (2022); and Czwikla et al. (2021) both of these discussed the use of random effects models in meta-analysis. Kanters emphasizes the importance of noticing variance between research. Meanwhile, Czwikla highlights the need of an accurate statistical inference.(Siangphoe & Archer, 2016) and (Li & Begg, 1994) further explores the application of random effects models in specific contexts, such as gene expression studies and combinations of controlled and uncontrolled studies. These studies demonstrate the versatility and importance of random effects models in analyzing varying study effect sizes and different sample distributions. Heterogeneity tests were carried out by examining Q statistics and p values to see the variance in effect sizes between studies. The null hypothesis (Ho) states that there is no difference in effect size variance between studies, while the alternative hypothesis (Ha) states that there is heterogeneity in effect size variance between studies. If Ho is rejected, this indicates that the variance of the effect sizes of all the studies analyzed is heterogeneous, so that moderator variables can be analyzed to reveal the heterogeneity of the influence of project-based learning on mathematical reasoning abilities.The analysis of moderator variables was carried out using JASP and Microsoft Excel with the following steps : (1) checking the average size effects and Q statistics or variance in every category to moderator variable, (2) calculating the variability effect in group (Qw) with adding up variance every category, (3) counting variance between group (Qb) by subtracting Q from Qw, (4) counting chi-square distribution or p-value using the formula "CHIDIST (Qb, df)". If $p < 0.05$, then the average of effect size in every category to moderator variables issignificantly different. So, the moderator variables influence the effectiveness of Project-Based Learning toward students' mathematical reasoning skills compared to a traditional learning model.

Publication bias is a significant consideration in meta-analysis, which leads to an overestimated impact and the possibility of missing findings (van Aert et al., 2019). However, the detection of publication bias is a challenging thing, with standard score test statistics based on the Copas selection model showing irregular behavior (Duan et al., 2020). Inappropriate application of statistical tests for funnel plot asymmetry and common methods for detecting publication bias are common in meta-analyses (Ioannidis & Trikalinos, 2007). To address this issue, experts recommend the inclusion of publication bias analysis in meta-analyses, using tools such as fail-safe N analysis, funnel plots, and sensitivity analysis(Oswald, 2009). This study evaluated publication bias using Funnel plots and Egger's test. Funnel plots show the distribution of effect sizes from each primary study, whether they are distributed symmetrically around a vertical line or not. If the distribution is symmetrical, the meta-analysis is considered free of publication bias (Retnawati et al., 2018). However, if the symmetry of the Funnel plot is difficult to interpret, Egger's test is used to test the symmetry of the effect size distribution. In the Egger test, if the p value > 0.05, then the distribution of effect sizes in the Funnel plot is considered symmetrical, indicating the absence of publication bias in the meta-analysis. Additionally, the fail-safe N was used to estimate the number of studies with non-significant results (that were not published) required to make the average effect size statistically insignificant. In detail, this method is explained in Figure 1.

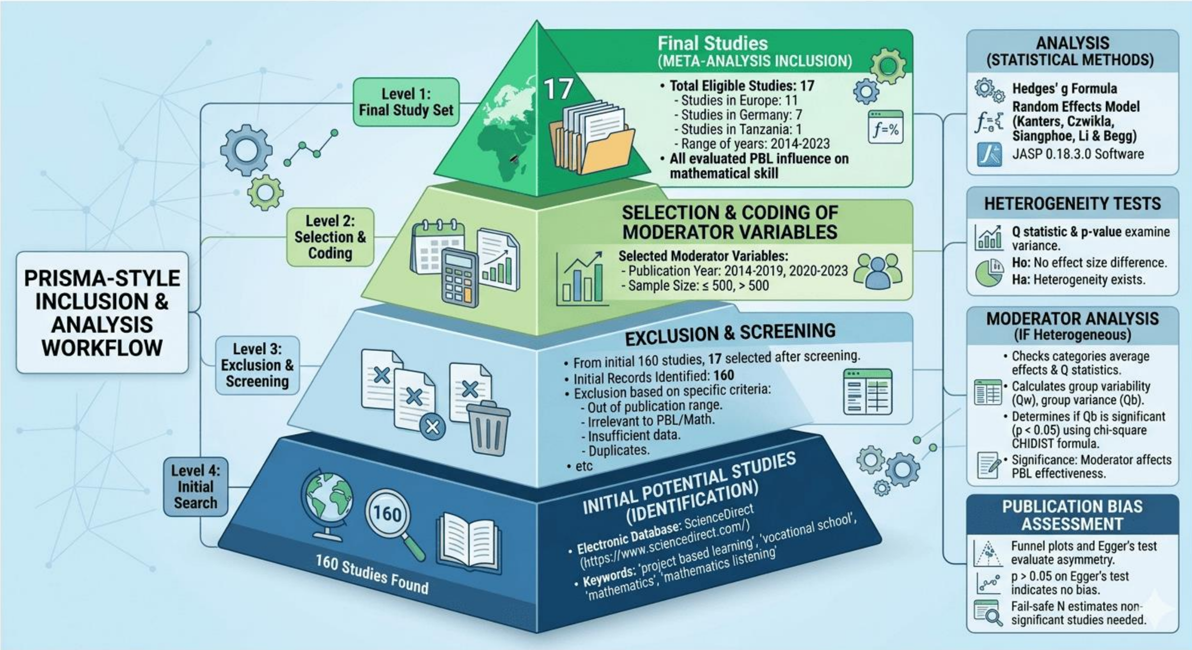

Figure 1. Pyramid Diagram

RESULTS AND DISCUSSION

The meta-analysis results show that project-based learning significantly improves students' mathematical skills. In this analysis, 17 studies have been transformed and analyzed using JASP. The results of the fixed and random effects analysis show that the overall model coefficient is significant ($p < 0.001$) and there is also a significant residual heterogeneity ($p < 0.001$). This means that the variables in the model have a significant influence, but the variation between studies is greater than expected.

The estimated coefficient for the intercept in the model is 71,872, which indicates that when all independent variables are zero, the dependent variable is estimated to be 71,872. A very small p value (< 0.001) indicates that the results are highly statistically significant. The log-likelihood value is -65.938, deviance is 131.876, AIC is 135.876, BIC is 137.421, and AICc is 136.799, indicating that the model has a good fit with the observation data. The results of the residual heterogeneity analysis show an estimate of τ^2 of 220.092, τ of 14.835, I^2 of 99.872%, and H^2 of 778.759. This indicates a high degree of heterogeneity among the studies in the analysis. The p-value in the Rank Correlation Test for Funnel Plot Asymmetry is 0.655, indicating that the funnel plot is symmetrical, which means there is no indication of publication bias.

In this discussion, we can draw several conclusions: (1) Project-based learning significantly improves students' mathematical abilities; (2) The coefficient model has a significant predictive power, but there is a significant residual heterogeneity; (3) The estimated coefficient for the intercept in the model indicates that learning based projects have a significant influence on mathematical skills; (4) The model has a good fit to the observational data, but there is an inter-study variation that is not explained by the model; (5) There is a high degree of heterogeneity among the studies in the analysis; (6) There is no indication of publication bias in this analysis.

Thus, these results indicate that learning-based Projects can basically improve students' mathematical skills but it is necessary to consider other factors that can influence these results.

Metadata

The metadata from 17 research or studies after detailed transformation can be seen in Table 1.

Table 1. Transformed Meta Data of 17 Studies

Study	Researcher Name	Country	Continent	Respondent	ICE	S.E
Study 1	(Ruzek et al., 2022)	Germany	Europe	8394	49.33	0.29
Study 2	(Straub et al., 2021)	Germany	Europe	60	64.04	2.85
Study 3	(Ren et al., 2023)	China	Asia	317	94.70	2.05
Study 4	(Ndijuye & Rao, 2019)	Tanzania	Africa	195	71.43	1.72
Study 5	(Yotyodying & Wild, 2019)	Germany	Europe	343	83.20	2.31
Study 6	(Capron Puozzo & Audrin, 2021)	Switzerland	Europe	23	86.39	3.38
Study 7	(Greisen et al., 2021)	Germany	Europe	6852	85.31	0.07
Study 8	(Vieluf & Göbel, 2019)	Germany	Europe	2047	89.58	0.38
Study 9	(Akyıldız et al., 2021)	Turkey	Europe	2226	46.92	0.47
Study 10	(Decristan et al., 2023)	Germany	Europe	932	71.00	4.63
Study 11	(Datu & Yuen, 2020)	China	Asia	273	58.66	0.84
Study 12	(Kirsch & Vaiouli, 2023)	Luxembourg	Europe	332	51.33	1.74
Study 13	(Benita et al., 2022)	Peru	America	622	80.10	0.67
Study 14	(Yusof et al., 2015)	Malaysia	Asia	192	64.80	2.68
Study 15	(Estabrooks & Couch, 2018)	USA	America	443	84.60	1.00
Study 16	(Wieduwilt et al., 2023)	Germany	Europe	205	77.65	1.43
Study 17	(Martínez Agudo, 2019)	Spanish	Europe	318	63.34	1.13

Table 1 depicts the metadata of 17 transformed studies. Each row represents a single study and includes information such as the study ID, the researchers' names, the publication year, the country and continent of origin, the number of participants, the calculated effect size, and its corresponding standard error.

This table provides important information regarding the characteristics of the studies involved in the meta-analysis, including the location where the studies were conducted, the sample size used in each study, and the effect measurement results obtained from each study.

Analysis Results with JASV

Below are presented the results of the JASV analysis, namely Fixed and Random Effects, Coefficients, Fit measures, Residual Heterogeneity Estimates, Rank correlation test for Funnel plot asymmetry, Forest Plot, Funnel Plot, Regression test for Funnel plot asymmetry ("Egger's test"), Influence Measures, File Drawer Analysis, and Analysis Results Moderator Variables.

Fixed and Random Effects

Table 2. Fixed and Random Effects

	Q	df	p
Omnibus test of Model Coefficients	391.916	1	< .001
Test of Residual Heterogeneity	22384.599	16	< .001

Note. p -values are approximate.

Note. The model was estimated using Restricted ML method.

In the Omnibus Test of Model Coefficients row, the Q value (391.916) is a statistical test for overall coefficient model. Degree of freedom (df) of 1 indicates that there is one parameter tested in context This. The p-value (< .001) is very small, indicating that model coefficients in general are statistically significant. It means that there is strong evidence of at least one coefficient in different models from zero. This indicates that this model's own strength has a significant predictive value.

In the Test of Residual Heterogeneity row, the Q value (22384.599) is a statistical test for residual heterogeneity. Degree of freedom (df) of 16 is usually related to the amount of studies which are reduced by the number of parameters in the model. The p-value (< .001) is very small, indicating the existence of statistically significant residual heterogeneity. It means that variation between studies is bigger than expected if there is a random variation. In other words, there is a variability that could not be explained by the model due to other factors that are not included in the model.

In general, the model significance: The Omnibus test shows that coefficient model is significant, indicating that variables in the model have a significant effect. The residual heterogeneity: The residual heterogeneity test shows the existence of significant heterogeneity, which means that the model might needs to consider additional factors or use a more complex approach for handling variation between studies. However, in general it can be concluded that project-based learning basically can increase mathematical skill.

Coefficients

Table 3. Coefficients

	Estimate	Standard Error	z	p
intercept	71,872	3,630	19,797	< .001

Note. Wald test.

Based on the Coefficients table, the estimation value for the intercept (constant) in the model is 71,872. It means that when all variables are independent in the zero model value, the prediction value for dependent variable is 71,872. The standard error from the intercept estimation is 3,630, which shows that the estimation size is probably different from the actual score due to the number of data sample. The z value is 19.797, which is the estimated ratio toward the (estimated) standar error, showing how much different (in unit standard deviation) the intercept estimation from zero. A very small p-value, which is less than 0.001, shows that the results are very statistically significant. In other words, there is a strong evidence that the intercept is not the same as zero.

With a very small p-value (< 0.001), we can conclude that the intercept in this model is statistically significant. It means that the intercept value of 71,872 is very likely not the result of chance. The intercept estimation of 71,872 shows that when all independent variables are worth to zero, the dependent variable is estimated worth to 71,872, giving a starting point or baseline in a predictive model. A relatively small standar error (3.630) and a very high z value (19.797) show that the intercept estimation is reliable and significant. By overall, these results show that the intercept in the model is very significant and provides substantial initial predicted value, which support the reliability and validity of the model used.

Fit measures

Table 4. Fit measures

	REML
Log-Likelihood	-65,938
Deviance	131,876
AIC	135,876
BIC	137,421
AICC	136,799

Based on the Fit Measures table (Table 4), the obtained Log-Likelihood value is -65.938, which is an indicator of how good the model fits with the observational data. The higher Log-Likelihood value, the better the fit between the model and the data. The deviance value of 131,876 also measures the model's ability to estimate the data, where a lower deviance value indicates a better fit between the model and the data. Deviance is often used in model comparsons, where the model with lower deviance is considered better.

The AIC (Akaike Information Criterion) value of 135,876 denotes a measure that combines model fit with its complexity. The lower the AIC value, the better the model, taking into account the fit to the data and the complexity of the model. BIC (Bayesian Information Criterion) has a value of 137,421, which is another measure for comparing models. Although like AIC, BIC imposes a slight penalty for complex models, and lower BIC values indicate better models.

The AICC (Corrected Akaike Information Criterion) value of 136,799 is the customized version of AIC which is more suitable for smaller sample. AICC gives more penalties for complex models rather than AIC, and a lower value of AICC low shows a better fit model.

From the presented fit measures, the model with higher Log-Likelihood, lower deviance, as well as lower AIC, BIC, and AICC are considered better. This matter indicate show fit a model with the observational data, where a higher value signifies a better fit between the model and the data.

Residual Heterogeneity Estimates

Table 5. Residual Heterogeneity Estimates

	Estimate
τ^2	220,092
T	14,835
I^2 (%)	99,872
H^2	778,759

The analysis results with JASV in the table *Residual Heterogeneity Estimates* show the estimation of residual heterogeneity as follows: (a) Estimated τ^2 (Tau Squared) is 220,092. This indicates variability between studies that could not be explained by the model. The higher the value of τ^2, the bigger heterogeneity between studies; (b) Estimated τ (Tau) is 14,835. This is the root square of τ^2 and gives variability estimation between studies in effect unit of measure; (c) The I^2 (I-squared) value of 99.872% indicates the proportion of variability between studies that is due to heterogeneity rather than measurement error. The higher I^2 value, the bigger the heterogeneity between studies; (d) The estimated H^2 (H-squared) is 778,759. H-squared is a alternative measurement for I-squared and shows the variability proportion between studies which are caused by heterogeneity.

This result indicates that there is a high level of heterogeneity among studies in the analysis, with a bigger part of variability which is explained by heterogeneity rather than error measurement.

Rank correlation test for Funnel plot asymmetry

Table 6. Rank correlation test for Funnel plot asymmetry

	Kendall's τ	p
Rank test	0.088	0.655

In the Rank correlation test for Funnel plot asymmetry table, Kendall's column shows a coefficient correlation between size effect and variance. To determine the connection of both, p-values are compared with alpha value = 0.05. If p-value < alpha = 0.05, we must reject the null hypothesis or the the funnel plot is asymmetrical. Conversely, if p-value >= alpha = 0.05, we must accept the null hypothesis or the funnel plot is symmetrical, which means that there is not any indication of publication bias. This table shows the p-value is 0.655 >= alpha = 0.05. So, the funnel plot is symmetrical, which means that there is not any indication of publication bias.

Plots

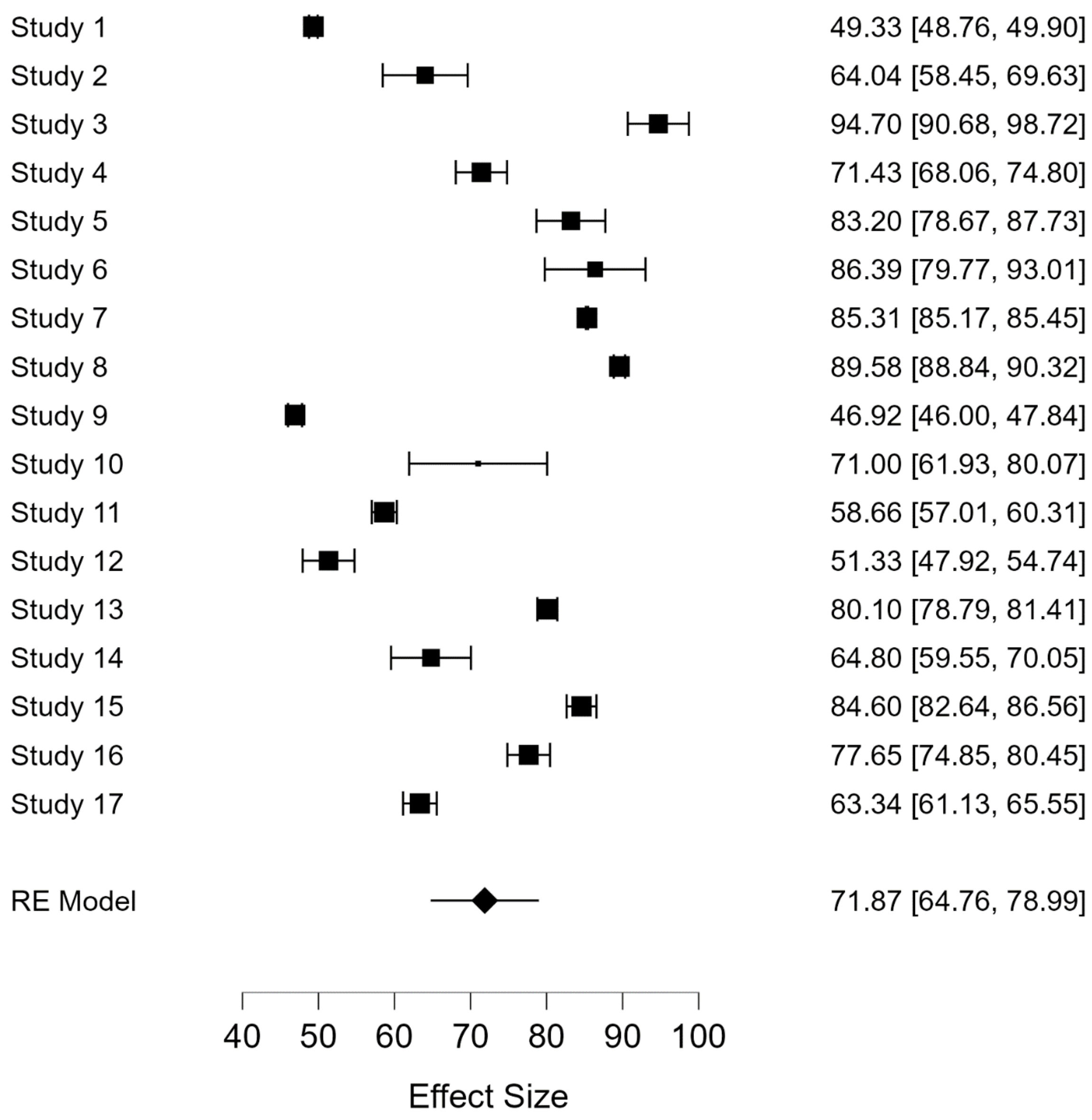

Figure 2. Forest Plot

Seventeen studies in the meta-analysis confirmed that the mean test indicates a significant difference in effect size variance (Q = 67.474; p < 0.001). This indicates the possibility of analyzing moderator variables to identify sources of variance between effect sizes. The following is an analysis of moderator variables in this meta-analysis research.

Funnel Plots

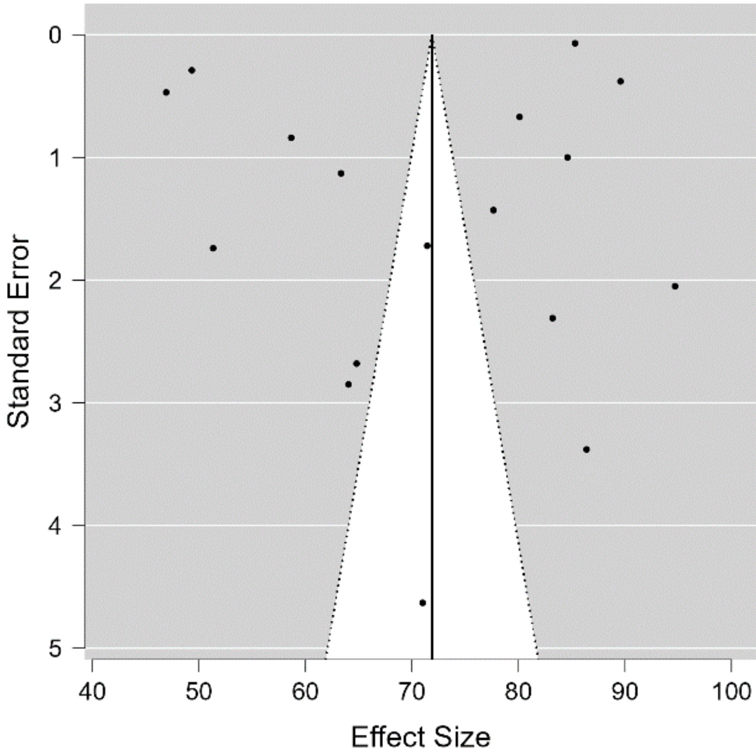

Figure 3. Funnel Plot

In the Forest Plot Image, if the study shows a publication bias, then the summary effect of the fixed-effect model will be shifted or become lower than the obtained previous summary effect (before analyzing using the Trim-Fill method), and the number of sample study will automatically increase (with labels: filled 1, filled 2, and so on). On the other hand, if there is not any indication of publication bias, the summary effect of the fixed-effect model will still be the same as the previous summary effects (before analyzing using the Trim-Fill method), and the number of research samples did not increase.

In the Funnel Plot Figure, if the study indicated a publication bias, there is an open circle on the plot (indicating missing or unpublished studies that needs to be added) and a circle closed (showing the original sample of the study).

If the study showed the existence of publication bias, the model is asymmetrically formed. Black circles would be centralized at the top (large-sized studies), while some medium-sized studies would disappear in the middle, and many small studies would disappear at the bottom. If the missing study is in the bottom left, it indicates that a small study whose results were not statistically significant is missing, and vice versa. In this study, the funnel plot has not shown symmetry, so further analysis is needed, namely by looking at the values of *Egger's test* and *Fail-safe N*. The number of samples and treatments can affect the symmetrical model and publication bias.

Regression test for Funnel plot asymmetry ("Egger's test")

Table 7. Regression test for Funnel plot asymmetry ("Egger's test")

	z	P
sei	0.456	0.648

In the *Rank Regression test for the Funnel plot asymmetry table*, Z column shows how big is thecoefficient regression. To testing them, the p values were compared with alpha value = 0.05. If p-value < alpha = 0.05, we must reject the null hypothesis (symmetric funnel plot) or conclude that the funnel plot is asymmetrical. Conversely, if p-value >= alpha = 0.05, we must accept the null hypothesis (symmetric funnel plot), which means that there is no indication of publication bias.

Because p > 0.05, which is 0.648, it confirms it that the funnel plot is symmetrical. Because the P value in Egger's test is >0.05, the funnel plot is symmetrical, which means that there is no publication bias. Thereby, it can concluded that there is no issue of publication bias in this meta-analysis study.

Influence Measures

Table 8. Influence Measures

	Std. Residual	DFFITS	Cook's Distance	Cov. Ratio	$\tau^2_{(-i)}$	$Q_{E(-i)}$	Hat	Weight
1	-1,650	-0.416	0.156	0.960	198,304	8615.974	0.060	5,986
10	-0.522	-0.130	0.018	1,110	230,457	22342.688	0.058	5,775
11	1,653	0.414	0.155	0.960	198,463	22349.064	0.059	5,876
12	-0.030	-0.008	6.779×10^{-5}	1,133	234,852	22343.223	0.059	5,909
13	0.768	0.191	0.037	1,089	225,826	22384.504	0.058	5,847
14	0.982	0.241	0.058	1,063	220,574	22383.265	0.057	5,693
15	0.930	0.235	0.056	1,072	221,906	9953.921	0.060	5,988
16	1,253	0.317	0.097	1,026	212,247	22025.483	0.060	5,985
17	-1,865	-0.470	0.191	0.921	190,039	16545.792	0.060	5,982
2	-0.056	-0.014	2.094×10^{-4}	1,123	233,752	22378.444	0.055	5,457
3	-0.912	-0.230	0.053	1,075	222,507	21575.193	0.060	5,969
4	-1,467	-0.367	0.126	0.993	205,287	22063.535	0.059	5,907
5	0.559	0.140	0.021	1,111	230.105	22371.797	0.060	5,976
6	-0.472	-0.118	0.015	1,114	231,243	22341.024	0.058	5,799
7	0.876	0.220	0.049	1,079	223,305	22380.110	0.060	5,961
8	0.389	0.097	0.010	1,122	232,525	22373.139	0.059	5,933
9	-0.579	-0.146	0.022	1,109	229,798	22096.566	0.060	5,954

The analysis results used JASV which expressed various influences measures on the model. The residual standard measures the distance of every data point from the regression line, with higher values indicating data points farther away from the regression line. DFFITS assesses the effect of an observation on the overall prediction, where a larger value indicates a more significant influence. Cook's Distance measure how much an observation affects the model as a whole, and a larger value indicates an observation that affects the model more. The Covariance Ratio is the ratio between the variance of the model with and without a given observation, where a value greater than 1 indicates a more significant observation in influencing the model. The estimation of τ^2(- i) and QE(- i) give a description about certain observation influences toward the heterogeneity and accuracy of the model after the observation is deleted. Regarding assessing the ability of observation to affect regression outcomes, with larger values indicating a more significant influence. Weight gives weight to the observations in the analysis, with larger values indicating more important observations. These findings provide an in-depth understanding of the influence of each observation on the model, as well as highlight which observations have a significant influence on the analysis.

Drawer Analysis

Table 9. Drawer Analysis

	Fail-safe N	Target Significance	Observed Significance
Rosenthal	2,040×10 $^{+6}$	0.050	< .001

In the Table 9, column Fail-safe N indicates the number of additional studies with an average zero effect measure that needs to be added to the research sample (in the context of a meta-analysis) so that our research conclusions are free from publication bias. The Target Significance column shows the limit value (one direction p 0.05), while the Observed Significance column shows the mark of the observed significance that would be compared to the Target Significance value.

Suppose K = 17. so 5(17) +10=85. The fail-safe value N is obtained, which is 2.040×10^{+6}, with a target significance of 0.05 and p <0.001. When the value of Fail-safe N totals are more than 5K+10 (where K is the total number of study). These results indicated that there is no publication bias in this meta-analysis study.

Publication Bias

To check publication bias, we used several methods, namely Funnel plot and Egger's test. Figure 2 shows the distribution of effect sizes across studies in a funnel plot analysis. The symmetry of the distribution of effect sizes in the Funnel plot was checked using the Egger test. The Egger test results show z = 1.456 and p = 0.648, which indicates that the distribution of effect sizes is symmetrical. These results indicate that there is no publication bias in this meta-analysis study.

Furthermore, in this study, the fail-safe N was 1191 (α = 0.05; p < 0.001). With a number of studies (k) of ten, the value of 5k + 10 = 5(10) + 10 is 60. Because the fail-safe N of 1191 is much higher than the value of 5k + 10, it can be concluded that there is no publication bias in meta studies -analyze this.

Table 10. Analysis Results Moderator Variables

Variable	Mean	Q	Df	Qw	Qb	P-Value
Whole	71,872	22384.599	16			0.648
Publication Year						
Group 1 (2014 - 2020)	73,687	1528.361	6	22383.351	1,248	2.639E-01
Group 2 (Year 2021 - 2023)	70,614	20854.99	9			
Research continent						
Group 1 (Europe)	69,761	21435.498	10	22075.132	309,467	2.853E-69
Group 2 (Non-Europe: Asia, America and Africa)	75,726	639,634	5			
Number of Respondents						
Group 1 (<500)	76,688	784,048	10	21558.8	825,799	1.327E-181
Group 2 (>500)	70,367	20774.752	5			

Proper citations of other works should be made to avoid plagiarism. When referring to a reference item, please use the reference number as in (Kleij, 2019) or (Brockett & Hiemstra, 2020) for multiple references. The use of "Ref (Hiemstra & Brockett, 2012)" should be employed for any reference citation at the beginning of a sentence. For any reference with more than 3 or more authors, only the first author is to be written followed by *et al*. (eg in (Geng et al., 2019)). Examples of reference items of different categories shown in the References section. Each item in the references section should be typed using 8 pt font size (Creswell & Clark, 2011;

Fraenkel et al., 2012; Honey & Marshall, 2003; Ismayilova & M.Klassen, 2019; Krueger & Casey, 2015; Mahvelati, 2021).

From the overall analysis, the average value of the variables studied is 71.872, with a total variance of 22384.599 and degrees of freedom of 16. The P-value is 0.648, which is greater than 0.05, indicating that there is no statistically significant difference in the overall data, indicates that the variables studied as a whole do not show significant variability.

In the analysis based on the year of publication, for the 2014-2020 period, the average value was 73,687 with a variance of 1528,361 and degrees of freedom 6. Meanwhile, for the 2021-2023 period, the average value was 70,614 with a variance of 20854.99 and degrees of freedom 9. Variance within the group (Qw) is 22383.351 and between-group variance (Qb) is 1.248. The P-value is 0.2639, which is greater than 0.05, indicating that there is no significant difference between research conducted in the two periods, meaning that the year of publication does not significantly influence the results.

In the analysis based on research continents, for research in Europe, the average value is 69.761 with a variance of 21435.498 and degrees of freedom 10. Meanwhile for research outside Europe (Asia, America and Africa), the average value is 75.726 with a variance of 639.634 and degrees of freedom 5. The within-group variance (Qw) is 22075.132 and the between-group variance (Qb) is 309.467. The P-Value of 2.853E-69, which is very small, shows that there is a very significant difference between research conducted in Europe and outside Europe, indicating that the location of the study has a significant influence on the results.

In the analysis based on the number of respondents, for research with less than 500 respondents, the average value is 76,688 with a variance of 784,048 and degrees of freedom of 10. Meanwhile, for research with more than 500 respondents, the average value is 70,367 with a variance of 20,774,752 and degrees of freedom of 5 The within-group variance (Qw) is 21558.8 and the between-group variance (Qb) is 825,799. The P-value is 1.327E-181, which is very small, indicating that there is a very significant difference based on the number of respondents, indicating that the number of respondents has a significant influence on the research results.

Overall, variability in the data was not significant, indicating stability in the results in general. However, there were significant differences in the results based on the location or continent of the study and the number of respondents, while the period of publication year did not have any significant influence. This shows that the research location and number of respondents greatly influence the research results, while the year of publication does not.

CONCLUSION

Project-based learning significantly improves students' mathematical skills. The results of the meta-analysis involving 17 studies show that project-based learninghas a significant predictive power and has a significant influence on mathematical skills. The coefficient estimate for the intercept in the model is 71,872, which indicates that when all independent variables are zero, the dependent variable is estimated to be 71,872. A very small p-value (< 0.001) indicates that the results are statistically highly significant. The model had a good fit to the observed data, but there was inter-study variation that was not explained by the model. There was a high level of heterogeneity among the studies in the analysis. There was also no indication of publication bias in this analysis. Thus, these results indicate that project-based learning can basically improve students' mathematical skills but it is necessary to consider other factors that can influence these results.

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