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Transformation of Student Science Achievement Through Project-Based Learning (PjBL): A Meta Analysis Study

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abstract

This study aims to evaluate the effectiveness of Project-Based Learning (PjBL) in enhancing students' science achievements through meta-analysis study. By selecting documents in Scopus, ScienceDirect, and Sinta Database using the PRISMA method, 20 documents were obtained and covering 29 studies from 2016 to 2024 which were analyzed using a random-effects model by R-Studio Program. The study results indicate that PjBL has a significantly positive impact on students' science achievements, with an average effect size of 1.12. Variability analysis revealed that the effectiveness of PjBL varies based on the education level, the type of skills developed, geographical location, and sample size. The highest effectiveness of PjBL was found at the elementary and high school levels, with a greater impact on the development of soft skills than cognitive skills in science achievement. The impact of PjBL was also more significant in Africa compared to Asia and Europe. This study underscores the importance of integrating PjBL into the educational curriculum to enhance student achievement in science learning, especially in diverse contexts. These findings provide a strong foundation for educators, policymakers, and researchers to develop and implement effective PjBL strategies.

1. Introduction

Science achievement refers to the level of knowledge, understanding, and skills students acquire in science. It is a critical aspect of modern education, as science literacy is essential for navigating and contributing to a world increasingly shaped by technology and scientific advancements (Müftüoğlu & Sahin, 2024; Suherman & Vidákovich, 2022). High levels of student achievement in science not only reflect a firm grasp of scientific concepts but also the ability to think critically, solve problems, and engage in scientific inquiry (Djidu & Istiyono, 2023; Istiyono, 2020; Retnawati, 2016). Promoting high levels of science achievement is vital for preparing students for future careers in STEM, fostering scientific innovation, and addressing global challenges like climate change, healthcare, and sustainable development. Therefore, improving science education and student engagement in science are key priorities for educational systems worldwide.

The 21st-century learning skills are the foundation that enables individuals to succeed in an increasingly complex and interconnected world. An education system focusing on developing these skills will help students achieve academic success and become competent, innovative, and responsible citizens (Putri et al., 2022; Zhang & Ma, 2023). By prioritizing 21st-century skills, we are preparing the next generation to face future challenges and contribute to the advancement of a better global society.

In the 21st-century education era, practical and innovative teaching methods are increasingly important to ensure students understand and apply the subject in real-world situations. One approach that is gaining popularity is Project-Based Learning (PjBL). PjBL is a student-centered learning approach that uses projects as the core of teaching and learning activities (Alemneh & Gebrie, 2024; Yu, 2024). The evolution of Project-Based Learning (PBL) is deeply intertwined with constructivist theories, which emphasize that learners build knowledge through experiences and reflections. PBL offers a learner-centered, collaborative learning system where students complete projects independently and in teams. This approach aims to equip students with new skills and knowledge through practical application, fostering an environment where learning is active and integrative (Alemneh & Gebrie, 2024; Marnewick, 2023; Yu, 2024). In PjBL, students actively and deeply explore complex and real-world problems or challenges. This method aims to make learning more relevant and engaging by involving students in projects that require problem-solving, decision-making, investigation, and reflection (Ling et al., 2024; Pupik Dean et al., 2023; Wang, 2023).

The implementation of PjBL in learning has become a topic of great interest among researchers and education practitioners. This interest is due to several studies showing that PjBL implementation can positively transform student learning outcomes and achievements (Apriany et al., 2020; Yarno et al., 2022). For instance, students engaged in PjBL tend to have a deeper understanding of the material, show improved analytical skills, and are better prepared to face real-world challenges (Adekantari et al., 2020; Fitra et al., 2024; Shin, 2018). Additionally, the engagement and practical application of acquired knowledge can enhance students' academic performance (Putri et al., 2022).

Although PjBL has been recognized as an effective learning method in improving student achievements in science learning, most PjBL research has been conducted in developed countries with adequate resources (Chen & Yang, 2019; Learning & Physics, 2020). There is still limited research exploring the effectiveness of PjBL in developing countries or in resource-limited environments. Therefore, further PjBL studies are needed to understand how PjBL can be adapted and effectively applied in various educational contexts. A meta-analysis study is necessary to understand the impact of PjBL implementation on student learning comprehensively.

Meta-analysis studies play a crucial role in evaluating and understanding the impact of PjBL implementation on learning. By combining and analyzing data from various studies, meta-analysis provides deep and comprehensive insights into the effectiveness of PjBL, the factors influencing it, and the best ways to implement it in diverse educational contexts (Chen & Yang, 2019; Gao et al., 2024; Goyal et al., 2022a). The results of this meta-analysis can be used to strengthen educational policies and enhance teaching practices to improve student achievements in science learning. Therefore, this study aims to examine further how PjBL implementation can affect science student achievements. By understanding the positive impact of this method, educators can be more confident in integrating PjBL into their curriculum, thus creating a more dynamic, interactive, and effective learning environment for student development.

2. Method

To ensure the quality of the study, we strictly adhered to the meta-analysis criteria proposed by Glass (1976). This approach involved four main assessment procedures: literature collection, coding, effect size calculation, and moderating variable analysis. Ultimately, these steps culminated in a comprehensive exploration of the effect size and a thorough analysis of the study results.

This study employed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) method (Moher et al., 2015). This study followed the literature processing method outlined by Vrabel (2015) to identify articles that meet the subject matter requirements. The literature search, screening, and inclusion process is illustrated in Figure 1. The literature search was conducted from February to May 2024. The literature used includes national and international articles published between 2016 and 2024, with a final count of 20 articles. To ensure the quality of the study results, these articles were sourced from the databases ScienceDirect, Scopus, and Sinta (levels 1-3). The keywords used in the search were "Project-Based Learning" or "student science achievement" or "science learning outcome" or "learning achievement."

After collecting the articles, the next step was selecting articles aligned with the research objectives. To find articles that meet the subject matter requirements, this study applied several selection criteria: (1) duplicate literature must be removed; (2) the research must focus on the implementation of PjBL and its impact on learning outcomes; (3) the research must be quantitative, including both experimental and control groups; (4) complete data that allows for the calculation of effect size must be available.

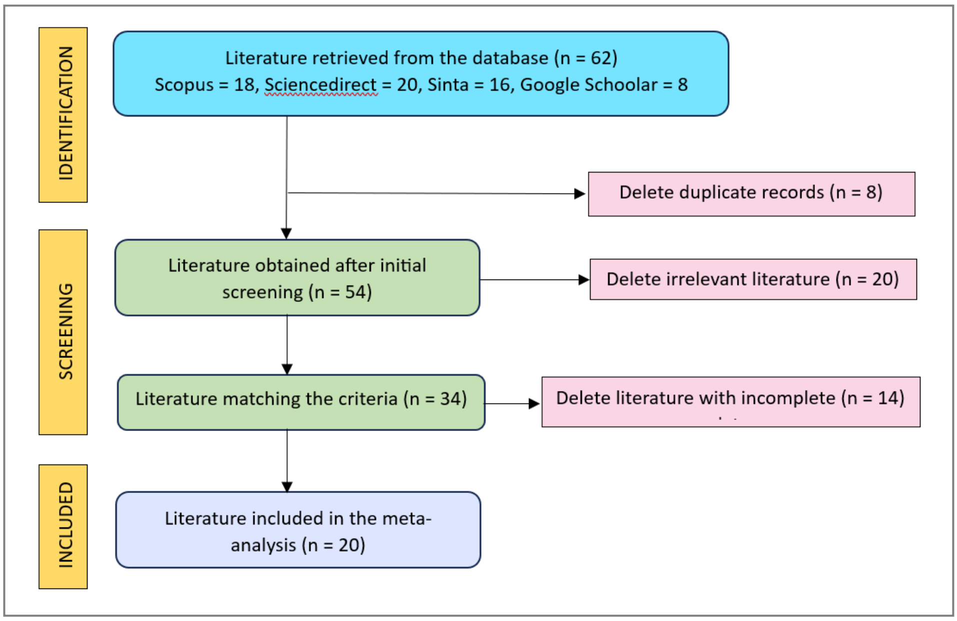

Figure 1. Flow chart literature screening

Coding was conducted based on the region where the study was carried out to compare the variability of the impact of PjBL. Therefore, the coding in this study includes three main aspects: region category, academic level, and group size. Furthermore, students' science achievements were categorized into cognitive and soft skills. From the 20 selected documents, 29 effect sizes were used in this meta-analysis study. Characteristics of studies included in the meta-analysis in Table 1.

Table 1. Characteristics of studies included in the meta-analysis

No	Study	Year	Sample	Continent	Level	Science Achievement
1	Ai-Jou Pan	2023	140	Asia	Senior High School	Cognitive Skills
2	Isna A.	2018	64	Asia	Senior High	Cognitive Skills

No	Study	Year	Sample	Continent	Level	Science Achievement
	Mukhayyaroh				School	
3	Siti Mega Farihatun	2019	66	Asia	Senior High School	Cognitive Skills
4	Juwita Amalda	2023	28	Asia	Senior High School	Cognitive Skills
5	Wiki A priany	2020	76	Asia	Elementary School	Cognitive Skills
6	Simegn Alemneh	2024	94	Africa	Senior High School	Cognitive Skills
7	Bojan D. Lazić	2021	147	Africa	Elementary School	Cognitive Skills
8	Dahlia N. Asri	2017	146	Asia	Middle School	Cognitive Skills
9	Dahlia N. Asri	2017	148	Asia	Middle School	Cognitive Skills
10	Safaruddin	2020	59	Asia	Elementary School	Cognitive Skills
11	Safaruddin	2020	59	Asia	Elementary School	Soft skills
12	Wekesa, N. Wafula	2016	80	Africa	Middle School	Cognitive Skills
13	Wekesa, N. Wafula	2016	80	Africa	Middle School	Cognitive Skills
14	Wekesa, N. Wafula	2016	80	Africa	Middle School	Cognitive Skills
15	Myeong-Hee Shin	2018	158	Asia	Elementary School	Soft skills
16	Myeong-Hee Shin	2018	158	Asia	Elementary School	Soft skills
17	Dominggus R	2019	40	Asia	Senior High School	Cognitive Skills
18	Dominggus R	2019	40	Asia	Senior High School	Cognitive Skills
19	Popy Adekantari	2020	72	Asia	Senior High School	Cognitive Skills
20	Abd. Syakur	2020	65	Asia	Higher School	Cognitive Skills
21	I Wayan Santyasa	2020	62	Asia	Senior High School	Cognitive Skills
22	I Wayan Santyasa	2020	62	Asia	Senior High School	Cognitive Skills
23	Alfyananda K.Putra	2021	72	Asia	Senior High School	Cognitive Skills
24	Alfyananda K. Putra	2021	72	Asia	Senior High School	Cognitive Skills
25	Intan Kartika Sari	2018	54	Asia	Elementary School	Soft skills
26	Suherman	2020	59	Asia	Middle School	Cognitive Skills
27	Yarno	2022	130	Asia	Middle School	Cognitive Skills
28	Rizki Fitra	2024	40	Asia	Senior High School	Cognitive Skills
29	Ahmad M. Mahasneh	2018	79	Eropa	Higher School	Cognitive Skills

The meta-analysis in this study used a comparison of group contrast approach, which involves one or more variables measured across two or more groups of respondents. Based on the completion of literature coding, the calculation of effect sizes, including sample sizes, standard deviations, and mean values, was performed by extracting relevant experimental data from the literature.

The analysis in this study was conducted using the R program, which included: (1) heterogeneity analysis to determine the model used in the analysis to compare effect sizes, (2) calculating the summary effect, (3) calculating effect sizes using the Standardized Mean Difference (SMD) since the data in this study do not have the same scale (Cheung, 2015), (4) detecting publication bias using a funnel plot, Egger's test, and fail-safe N (FSN) to estimate the number of studies with non-significant results, and (5) moderator variable analysis to identify sources of variation among effect sizes and differences among subgroups.

3. Result and Discussion

The meta-analysis in this study involved 20 pieces of documents with a total of 29 studies. These documents were strictly selected to ensure they met the specified criteria. Based on the data obtained, several analyses were conducted as follows:

Heterogeneity Test

The heterogeneity test was conducted to evaluate the extent to which the results from individual studies combined in the meta-analysis varied more than expected. Heterogeneity indicates systematic variation among studies, which can be caused by factors such as differences in study populations, research designs, interventions, or outcome measurements (Mahasneh & Alwan, 2018; Pan et al., 2023; Syakur et al., 2020). This study examined the suitability of the model used in the analysis to compare effect sizes. The following are the results of the heterogeneity test through the Q-Cochran statistic.

Table 2. Fixed and random effects of heterogeneity

	Q	df	p
Omnibus Test of Model Coefficients	9.685	1	0.002
Test of Residual Heterogeneity	1000.65	28	< .001

Note. *p* -values are approximate.

Table 2, which is presented, shows two statistical tests related to heterogeneity, commonly used in meta-analysis. The first test, the Omnibus test of Model Coefficients, has a Q statistic of 9.685 with 1 degree of freedom (df) and a p-value of 0.002. This test evaluates whether significant heterogeneity exists in the overall model coefficients across different studies. A significant p-value (0.002) indicates that the variation in effect sizes is not entirely due to random sampling error, but significant heterogeneity exists in the model's coefficients.

The second test, the Test of Residual Heterogeneity, has a very large Q statistic of 1000.65 with 28 degrees of freedom and a very small p-value (less than 0.001). This test assesses whether there is still unexplained heterogeneity after accounting for the factors in the model (Borenstein, 2009). This highly significant result suggests that although the model includes some predictors, there remains substantial variability among the studies that the model cannot explain.

Overall, these results indicate significant heterogeneity in the model coefficients, and despite accounting for some factors, there is still unexplained variability. Therefore, the Random Effect model is more suitable for estimating the mean effect size of the 29 analyzed studies. This result also suggests the potential to investigate moderator variables that influence the relationship between PjBL and student science achievements.

Summary Effect

The Summary Effect or Mean Effect Size is a measure summarized from the results of several individual studies combined in a meta-analysis. Using this measure is important in meta-analysis as it provides an overall measure of the investigated effect, facilitates the interpretation of results, enhances statistical power, and provides a basis for further analysis (Retnawati et al., 2018). The forest plot of the summary effect is shown in Figure 2.

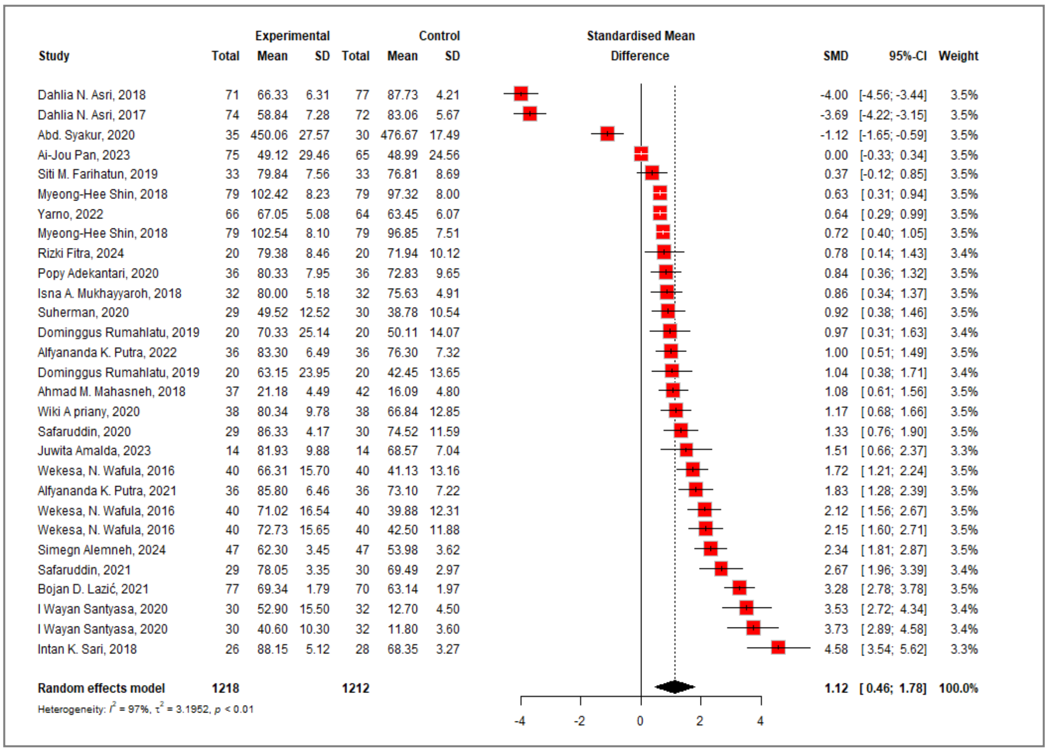

Figure 2. Forest plot of summary effect

The results of the meta-analysis using the random effects model (SMD) show that the average effect size from the 29 studies is 1.12 ($p < 0.01$) with a 95% confidence interval (CI) ranging from 0.46 to 1.78, which falls into the very high effect size category. The effect sizes from these studies indicate that the impact of PjBL on student science achievements varies, ranging from -4.00 to 4.58. Further analysis was conducted, and the results are presented in Table 3.

Table 3. The result of the summary effect

				95% Confidence Interval		
	Estimate	**Standard Error**	**z**	**p**	**Lower**	**Upper**
Intercept	1.124	0.328	3.34	0.0008	0.464	1.784

The data in Table 3 shows that the estimated value and z-value obtained are 1.124 and 3.34, respectively. Meanwhile, the obtained p-value is 0.0008 or smaller than the specified significant level of 0.05. Because p-value < 0.05, it can be concluded that the Random Effect model used in this study shows a significant correlation between PjBL and student acience achievemnts. The effect of PjBL on science achievements is in the moderate category (r_{Ez} = 0.328) (Cohen, 1988).

Publication Bias Evaluation

A good meta-analysis study is a study that does not have publication bias issues. In this case, publication bias can be identified through the funnel plot formed by the standard error and standardized mean difference (SMD). An asymmetrical funnel plot indicates no publication bias. Figure 3 is the funnel plot from the results of this study.

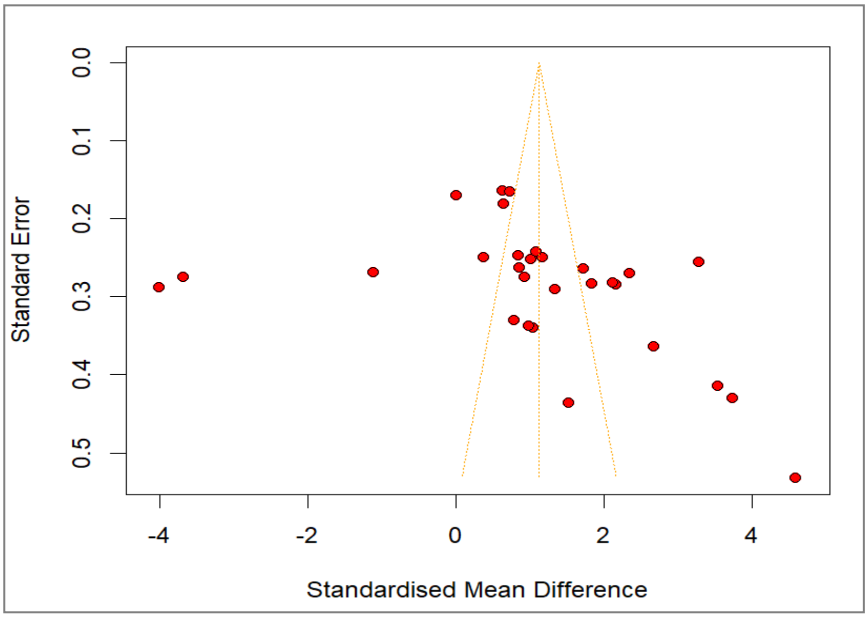

Figure 3. The Funnel Plot of publication bias

The Funnel Plot of Publication Bias Figure 3 shows that the data distribution in the funnel plot makes it difficult to conclude whether it is symmetrical or not. Therefore, it is necessary to perform the Egger test to examine the symmetry of the data further. The following are the results of the Egger test performed in Table 4.

Table 4. Regression test for Funnel plot asymmetry

	z	p
sei	6.4541	0.1172

Table 4 shows that the obtained p-value is 0.1172 and the z-value is 6.4541. This p-value is greater than the significance level of 0.05 (0.1172 > 0.05). If p-value > 0.05, the funnel plot is said to be symmetrical. This means there is no publication bias issue in the meta-analysis study conducted. To strengthen this argument, the Fail-Safe N test is performed.

Table 5. The Result of Fail-Safe N

	Fail-safe N	Target Significance	Observed Significance
Rosenthal	3983	0.05	< .001

Table 5 provides information that there are 3,983 studies suspected of being biased or not conducting studies properly, so these studies are not reported or published. Since k = 29, then 5k + 10 = 5(29) + 10 = 155. The obtained Fail-safe N value is 3,983, with a significant target of 0.05

and p < 0.001. Since the Fail-safe N value > 5K + 10, it can be concluded that there is no publication bias issue in the meta-analysis study conducted.

Moderator Variable Analysis

The moderator variable is a variable that influences the direction or strength of the relationship between the independent variable (PjBL) and the dependent variable (student science achievements). In the context of meta-analysis, the moderator variable is used to identify and explain differences in results from various studies analyzed (Lazić et al., 2021; Novarianing Asri et al., 2017; Retnawati et al., 2018). This study's moderator variables include grade level category, learning skill, continent, and sample size. The following are the results of the forest plot of the moderator variables in Figure 4.

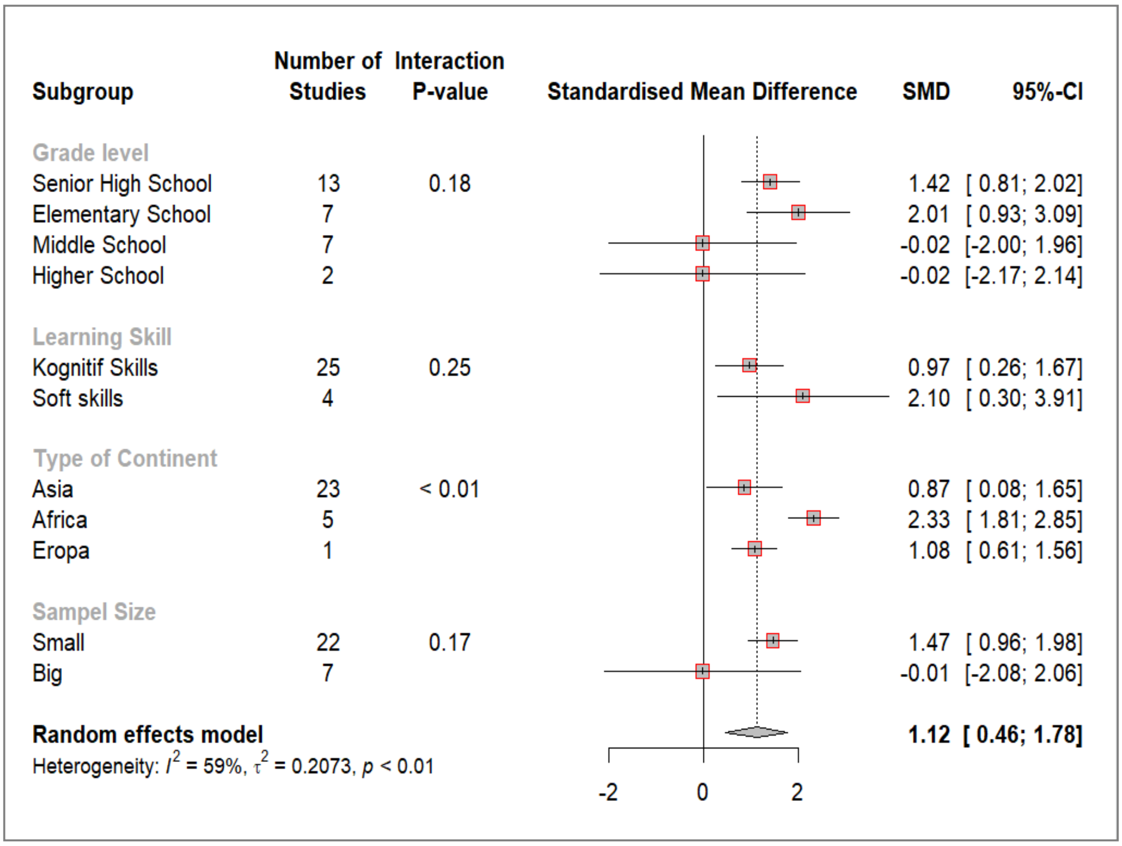

Figure 4. Forest plot of the moderator variable

The first moderator variable observed is the grade level, consisting of elementary school, middle school, senior high school, and higher school. The analysis results on the forest plot show that elementary school and senior high school have significant effect sizes (2.01 and 1.42). In contrast, middle school and high school have insignificant effect sizes of 0.02. However, the p-value for this moderator variable is 0.18 (p-value > 0.05), so it can be concluded that there is no difference in the relationship between PjBL and learning skills regarding grade level type. The relationship between PjBL and learning is found to be strongest in studies at the elementary school level (r_{xx} = 2.01).

The second moderator variable observed is learning skills, consisting of cognitive skills and soft skills. The results of the analysis show that PjBL with soft skills has a stronger relationship (2.10) compared to cognitive skills (0.97). Meanwhile, the p-value for this moderator variable is

0.25 (p-value > 0.05), so it can be concluded that there is no difference in the relationship between PjBL and student science achievements regarding learning skill type.

The third moderator variable observed is based on the region or continent: Asia, Africa, and Europe. The results on the forest plot show that the African continent has the most significant effect size (2.33), while the Asian and European continents have effect sizes of 0.87 and 1.08, respectively. The p-value for this variable is < 0.01 (p-value < 0.05), so it can be concluded that there is a difference in the relationship between PjBL and learning skills in terms of region type. The relationship between PjBL and learning skills is strongest in Africa.

The last moderator variable observed is the sample size. The results on the forest plot show that small samples have a more significant effect size (1.47) compared to big samples (-0.01). The p-value for this variable is 0.17 (p-value > 0.05). Therefore, it can be concluded that there is no difference in the relationship between PjBL and learning skills (student science achievements) in terms of sample size.

The meta-analysis conducted on the impact of Project-Based Learning (PjBL) on students' science achievements reveals significant insights into the effectiveness of this pedagogical approach. This study aggregated data from various research papers spanning from 2016 to 2024, focusing on different educational contexts, including diverse geographical locations, academic levels, and learning skills.

The meta-analysis demonstrated that PjBL positively influences student science achievements (learning skills), with an average effect size of 1.12. This indicates a high level of effectiveness, suggesting that students engaged in PjBL have better learning outcomes than traditional teaching methods. The significant p-value (p < 0.001) further reinforces the reliability of these findings. Several studies have also confirmed that PjBL is effective in improving academic achievement in various subjects across different school settings, enhancing students' science process skills, and enhancing overall student learning outcomes (Kong et al., 2024; Lee et al., 2024; Vasset & Sundal, 2024).

The heterogeneity test indicated substantial variability among the studies, justifying the use of a random-effects model. This variability can be attributed to differences in study designs, implementation contexts, and student demographics (Amalda et al., 2023; Arief & Mukhayyaroh, 2018; Zhang & Ma, 2023). The random-effects model's suitability highlights the diverse nature of PjBL's impact across different settings.

The analysis identified several moderating variables that influence the relationship between PjBL and student science achievement: 1) grade level, the effectiveness of PjBL varies by educational level, with elementary and senior high school students showing the most significant gains. This could be due to students' different cognitive and developmental stages at these levels, making PjBL particularly effective in engaging younger learners and preparing older students for complex problem-solving (Adekantari et al., 2020; Goyal et al., 2022b; Shin, 2018); 2) learning skills, PjBL has a stronger impact on soft skills compared to cognitive skills. This aligns with the nature of PjBL, which emphasizes collaboration, communication, and critical thinking components of soft skills development (Fitra et al., 2024; Safaruddin et al., 2020); 3) geographical location, the impact of PjBL was found to be most pronounced in Africa, followed by Europe and Asia. This geographical variation might reflect differences in educational infrastructure, teacher training, and curriculum integration of PjBL (Farihatun, Siti, 2019; Wafula & Odhiambo, 2016; Suherman et al., 2020); 4) sample size, smaller sample sizes showed a more significant effect size, which could be due to the intensive nature of PjBL requiring close teacher-student interaction, often more feasible in smaller groups (Apriany et al., 2020; Marnewick, 2023; Yu, 2024).

Some of the above findings can have implications for implementing PjBL in Indonesian education. Educators and policymakers should consider integrating PjBL into curricula across various grade levels, particularly focusing on its implementation in elementary and senior high schools where it has shown significant benefits (Noah Wafula & Raphael Odhiambo, 2016). Emphasizing project-based approaches in curriculum design can enhance student engagement and foster essential 21st-century skills. Furthermore, regarding teacher training, given the variability in PjBL's effectiveness, there is a need for targeted teacher training programs (Ling et al., 2024; Wang, 2023). These programs should equip educators with the skills to design and facilitate effective PjBL experiences, tailored to different educational contexts and student needs. The pronounced impact of PjBL in resource-constrained environments, such as in many African contexts, underscores the importance of providing adequate resources and support to implement PjBL (Gao et al., 2024; Goyal et al., 2022a). This includes access to materials, technological tools, and professional development opportunities for teachers. The findings highlight the need for continued research, particularly in diverse and under-researched contexts. Future studies should explore how PjBL can be adapted to different educational environments and its long-term impact on various student science achievements.

Conclusion the meta-analysis affirms the effectiveness of Project-Based Learning in enhancing student science achievements across different contexts. By fostering active and integrative learning experiences, PjBL equips students with the necessary skills to succeed in an increasingly complex and interconnected world. The study's findings provide a robust foundation for educators, policymakers, and researchers to develop and implement PjBL strategies further, ensuring that students are well-prepared for future challenges.

4. Conclusion

The meta-analysis affirms the effectiveness of Project-Based Learning in enhancing student science achievements across different contexts. By fostering active and integrative learning experiences, PjBL equips students with the necessary skills to succeed in an increasingly complex and interconnected world. The study's findings provide a robust foundation for educators, policymakers, and researchers to develop and implement PjBL strategies further, ensuring that students are well-prepared for future challenges.

References

Adekantari, P., Su’ud, & Sukardi. (2020). The Influence of Instagram-Assisted Project Based Learning Model on Critical Thinking Skills Popy Adekantari Su ’ ud Sukardi. *Journal of Educational and Social Research*, *10*(6), 315–322. https://doi.org/10.36941/jesr-2020-0129

Alemneh, S., & Gebrie, G. (2024). The role of project-based learning in improving the writing ability and sub- writing abilities of 10th grade Amharic speaking students. *Social Sciences and Humanities Open*, *9*(September 2023), 100843. https://doi.org/10.1016/j.ssaho.2024.100843

Amalda, J., Karwur, H. M., & Ramadhan, M. I. (2023). Penerapan Model Pembelajaran Project Based Learning untuk Meningkatkan Hasil Belajar Siswa pada Mata Pelajaran Geografi. *GEOGRAPHIA : Jurnal Pendidikan Dan Penelitian Geografi*, *4*(1), 23–31. https://doi.org/10.53682/gjppg.v4i1.4065

Apriany, W. A., Winarni, E. W., & Muktadir, A. M. (2020). Pengaruh Penerapan Model Pembelajaran Project Based Learning (PJBL) terhadap Hasil Belajar Kognitif Siswa pada Mata Pelajaran IPA di Kelas V SD Negeri 5 Kota Bengkulu. *Jurnal Pembelajaran Dan Pengajaran Pendidikan Dasar*, *3*(2), 88–97. https://doi.org/10.33369/dikdas.v3i2.12308

Arief, S., & Mukhayyaroh, I. A. (2018). Penerapan project based learning untuk meningkatkan kreativitas, motivasi belajar dan hasil belajar. *Economic Education Analysis Journal*, *7*(1), 1–14.

Chen, C. H., & Yang, Y. C. (2019). Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators. *Educational Research Review*, *26*(January), 71–81. https://doi.org/10.1016/j.edurev.2018.11.001

Djidu, H., & Istiyono, E. (2023). *Quality of Performance Assessment Instruments for Educators in Higher Education : Implementation of Factor Analysis And Generalizability Theory*. *7*(2), 144–159.

Fitra, R., Prasetya, F., & Adri, J. (2024). Exploration of the implementation of project-based learning in tehnical drawing courses toward. *Journal of Engineering Researcher and Lecturer*, *4*(1), 46–55. https://doi.org/10.58712/jerel.v3i1.128

Gao, X., Yan, D., Zhang, Y., Ruan, X., Kang, T., Wang, R., Zheng, Q., Chen, S., & Zhai, J. (2024). Comparison of the impact of team-based learning and lecture-based learning on nursing students' core competencies: A systematic review and meta-analysis. *Nurse Education in Practice*, *76*(March), 103945. https://doi.org/10.1016/j.nepr.2024.103945

Goyal, M., Gupta, C., & Gupta, V. (2022a). A meta-analysis approach to measure the impact of project-based learning outcome with program attainment on student learning using fuzzy inference systems. *Heliyon*, *8*(8), e10248. https://doi.org/10.1016/j.heliyon.2022.e10248

Goyal, M., Gupta, C., & Gupta, V. (2022b). A meta-analysis approach to measure the impact of project-based learning outcome with program attainment on student learning using fuzzy inference systems. *Heliyon*, *8*(8). https://doi.org/10.1016/j.heliyon.2022.e10248

Istiyono, E. (2020). *Pengembangan Instrumen Penilaian dan Analisis Hasil Belajar Fisika: Dengan Teori Tes Klasik dan Modern.* UNY Press.

Kong, S. C., Cheung, M. Y. W., & Tsang, O. (2024). Developing an artificial intelligence literacy framework: Evaluation of a literacy course for senior secondary students using a project-based learning approach. *Computers and Education: Artificial Intelligence*, *6*(February), 100214. https://doi.org/10.1016/j.caeai.2024.100214

Lazić, B. D., Knežević, J. B., & Maričić, S. M. (2021). The influence of project-based learning on student achievement in elementary mathematics education. *South African Journal of Education*, *41*(3), 1–10. https://doi.org/10.15700/saje.v41n3a1909

Learning, P. B., & Physics, L. (2020). Learning Physics. *International Journal of Instruction*, *13*(1), 489–508.

Lee, H.-I., Ignatyev, D., Shin, H.-S., & Tsourdos, A. (2024). Project-Based Learning Course Design for Multi-Agent Autonomy Using Quadrotors. *IFAC-PapersOnLine*, *58*(16), 107–112. https://doi.org/10.1016/j.ifacol.2024.08.470

Ling, Y., Zhou, L., Zhang, B., & Ren, H. (2024). Developing middle school students' problem-solving ability through interdisciplinary project-based learning. *Education for Chemical Engineers*, *46*(September 2023), 43–53. https://doi.org/10.1016/j.ece.2023.11.001

Mahasneh, A. M., & Alwan, A. F. (2018). The effect of project-based learning on student teacher self-efficacy and achievement. *International Journal of Instruction*, *11*(3), 511–524. https://doi.org/10.12973/iji.2018.11335a

Marnewick, C. (2023). Student experiences of project-based learning in agile project management education. *Project Leadership and Society*, *4*(August), 100096. https://doi.org/10.1016/j.plas.2023.100096

Mega Farihatun, Siti, R. (2019). Keefektifan Pembelajaran Project Based Learning (PjBL) Terhadap Peningkatan Kreativitas Dan Hasil Belajar. *Economic Education Analysis Journal*, *8*(2), 635–651. https://doi.org/10.15294/eeaj.v8i2.31499

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L. A., & PRISMA-P Group. (2015). Preferred reporting items for systematic review and meta-analysis protocols (prisma-p) 2015 statement. *Systematic Reviews*, *4*(1), 1–9.

Müftüoğlu, C. T., & Sahin, M. (2024). *Assessment Analytics in Education: design, Methods, and Solutions*. Springer. https://doi.org/10.1007/978-3-031-56365-2_8

Noah Wafula, W., & Raphael Odhiambo, O. (2016). Project Based Learning on Students' Performance in the Concept of Classification of Organisms among Secondary Schools in Kenya. *Journal of Education and Practice*, *7*(16), 25–31.

Novarianing Asri, D., Setyosari, P., Hitipeuw, I., & Chusniyah, T. (2017). The Influence of Project-based Learning Strategy and Self-regulated Learning on Academic Procrastination of Junior High School Students' Mathematics Learning. *American Journal of Educational Research*, *5*(1), 88–96. https://doi.org/10.12691/education-5-1-14

Pan, A. J., Lai, C. F., & Kuo, H. C. (2023). Investigating the impact of a possibility-thinking integrated project-based learning history course on high school students' creativity, learning motivation, and history knowledge. *Thinking Skills and Creativity*, *47*(September 2022). https://doi.org/10.1016/j.tsc.2022.101214

Pupik Dean, C. G., Grossman, P., Enumah, L., Herrmann, Z., & Kavanagh, S. S. (2023). Core practices for project-based learning: Learning from experienced practitioners in the United States. *Teaching and Teacher Education*, *133*(November 2022), 104275. https://doi.org/10.1016/j.tate.2023.104275

Putri, R. K., Bukit, N., & Simanjuntak, M. P. (2022). The Effect of Project Based Learning Model's on Critical Thinking Skills, Creative Thinking Skills, Collaboration Skills, & Communication Skills (4C) Physics in Senior High School. *Proceedings of the 6th Annual International Seminar on Transformative Education and Educational Leadership (AISTEEL 2021)*, *591*(Aisteel), 323–330. https://doi.org/10.2991/assehr.k.211110.103

Retnawati, H. (2016). Proving content validity of self-regulated learning scale (the comparison of aiken index and expanded gregory index). *Research and Evaluation in Education*, *2*(2), 155–164. https://doi.org/10.21831/reid.v2i2.11029

Retnawati, H., Apino, E., Kartianom, Djidu, H., & Anazifa, R. D. (2018). Pengantar Analisis Meta. In *Encyclopedia of Research Design*. Parama Publishing. https://doi.org/10.4135/9781412961288.n426

Safaruddin, S., Ibrahim, N., Juhaeni, J., Harmilawati, H., & Qadrianti, L. (2020). The Effect of Project-Based Learning Assisted by Electronic Media on Learning Motivation and Science Process Skills. *Journal of Innovation in Educational and Cultural Research*, *1*(1), 22–29. https://doi.org/10.46843/jiecr.v1i1.5

Shin, M.-H. (2018). Effects of Project-based Learning on Students' Motivation and Self-efficacy. *English Teaching*, *73*(1), 95–114. https://doi.org/10.15858/engtea.73.1.201803.95

Suherman, Prananda, M. R., Proboningrum, D. I., Pratama, E. R., Laksono, P., & Amiruddin. (2020). Improving Higher Order Thinking Skills (HOTS) with Project Based Learning (PjBL) Model Assisted by Geogebra. *Journal of Physics: Conference Series*, *1467*(1). https://doi.org/10.1088/1742-6596/1467/1/012027

Suherman, S., & Vidákovich, T. (2022). Assessment of mathematical creative thinking: A systematic review. *Thinking Skills and Creativity*, *44*(January). https://doi.org/10.1016/j.tsc.2022.101019

Syakur, A., Junining, E., & Sabat, Y. (2020). The Implementation of Project Based Learning (PBL) Model Towards the Result Student's TOEFL in 7th semester of Brawijaya University. *Journal of Development Research*, *4*(1), 41–46. https://doi.org/10.28926/jdr.v4i1.97

Vasset, F. P., & Sundal, H. (2024). Paediatric nursing: Implementation and evaluation of project-based learning in nursing studies. *Social Sciences and Humanities Open*, *10*(June). https://doi.org/10.1016/j.ssaho.2024.101022

Vrabel, M. (2015). Preferred Reporting Items for Systematic Reviews and Meta-Analyses. *Oncology Nursing ONF*, *42*(5), 552–554. https://doi.org/10.1188/15.ONF.552-554

Wang, Y. (2023). The role of computer supported project-based learning in students' computational thinking and engagement in robotics courses. *Thinking Skills and Creativity*, *48*(October 2021), 101269. https://doi.org/10.1016/j.tsc.2023.101269

Yarno, Y., Mustaji, M., Bachri, B. S., & Arianto, F. (2022). The Influence of Project-based Learning to Empower Students' Cognitive Abilities. *International Journal of Social Science And Human Research*, *05*(11), 5192–5199. https://doi.org/10.47191/ijsshr/v5-i11-49

Yu, H. (2024). Enhancing creative cognition through project-based learning: An in-depth scholarly exploration. *Heliyon*, *10*(6), e27706. https://doi.org/10.1016/j.heliyon.2024.e27706

Zhang, L., & Ma, Y. (2023). A study of the impact of project-based learning on student learning effects: a meta-analysis study. *Frontiers in Psychology*, *14*(July), 1–14. https://doi.org/10.3389/fpsyg.2023.1202728