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# EMPOWERING STUDENTS' ESSENTIAL SKILLS AND MOTIVATION THROUGH PROJECT-BASED LEARNING: A META-ANALYSIS

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## ABSTRACT

Project-Based Learning represents a transformative approach to education that aligns with the demands of the 21st century. By fostering critical thinking, collaboration, communication, and creativity, PBL equips students with the essential skills needed for success in an increasingly complex world. This meta-analysis examines the effectiveness of Project Based Learning (PBL) in enhancing student skills and motivation. By reviewing and synthesizing findings from multiple studies indexed in Scopus and accredited by Sinta over the past decade, this study provides a comprehensive evaluation of PBL's impact on educational outcomes. The meta-analysis includes 13 journal articles and 18 studies, assessing the effect sizes of PBL on various educational variables such as critical thinking, problem-solving, collaboration, and motivation. The results indicate a strong overall impact of PBL, demonstrating its significant positive influence on learning outcomes. Additionally, the findings suggest minimal publication bias, as evidenced by a relatively symmetrical funnel plot. Despite the observed heterogeneity due to variations in study settings, participant demographics, and PBL implementations, the overall effect remains substantial. This study underscores the importance of integrating PBL into educational curricula to foster essential 21st-century skills, enhance student engagement, and reduce achievement gaps among diverse student populations. Therefore, future research should focus on standardizing methodologies and exploring the sources of heterogeneity to further strengthen the generalizability of the findings.

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## 1. INTRODUCTION

In the ever-changing world of education, traditional learning methods are increasingly being replaced by more dynamic and interactive approaches. Therefore, (Kartini et al., 2021) these innovative approaches, Project-Based Learning (PBL) has emerged as a powerful pedagogical tool designed to enhance student skills comprehensively. Project-Based Learning is an instructional methodology that encourages students to learn and apply knowledge and skills through an engaging experience centered on the exploration and resolution of real-world problems (Setiyadi et al., 2024). In addition, (Wanglang & Chatwattana, 2023) this approach not only fosters a deeper understanding of the subject matter but also equips students with essential 21st-century skills such as critical thinking, collaboration, communication, and creativity. The need for students to acquire these skills has never been more pressing. (Mosier et al., 2016) as the global economy becomes increasingly interconnected and technologically advanced, the ability to think critically, solve complex problems, and work effectively with others has become crucial for success in both higher education and the workforce. Traditional educational methods often fall short in providing students with opportunities to develop these competencies. (Viana et al., 2019) PBL, by contrast, offers a student-centered approach that aligns educational outcomes with the demands of modern society. In conclusion, Project-Based Learning (PBL) offers a student-centered approach that effectively prepares students for the demands of modern society by fostering essential 21st-century skills.

In addition, the efficacy of Project-Based Learning in enhancing student skills has been widely documented in educational research. A meta-analysis (Mursid et al., 2022) highlighted that PBL significantly impacts student engagement and learning outcomes. (Jeon et al., 2014) research demonstrated that students participating in PBL activities exhibited higher levels of motivation and achievement compared to their peers in traditional learning settings. This increase in engagement is attributed to the relevance and authenticity of PBL projects, which provide students with a sense of purpose and real-world application of their knowledge. Moreover, studies have shown that PBL enhances critical thinking skills. According to (Syahril et al., 2021) students engaged in PBL are more likely to develop the ability to analyze complex issues, evaluate evidence, and construct well-reasoned arguments. These skills are fostered through the iterative process of inquiry, research, and reflection inherent in PBL. Similarly, a study by (Siburian et al., 2022) found that PBL students demonstrated superior problem-solving abilities compared to those in traditional classrooms. In other words, the collaborative nature of PBL also promotes the development of social skills, as students must work together to achieve common goals, negotiate roles, and resolve conflicts.

Communication skills are another critical area where PBL has shown significant benefits. (Alemneh & Gebrie, 2024) noted that PBL students frequently engage in discussions, presentations, and written reports, which help them articulate their ideas clearly and confidently. Therefore, (Abu Bakar et al., 2019) this continuous practice of communication not only improves their verbal and written skills but also prepares them for future professional environments where effective communication is paramount. In addition, (Mursid et al., 2022) creativity is also nurtured through PBL, as it encourages students to think outside the box and approach problems from multiple perspectives. (Ayish & Deveci, 2019) revealed that PBL fosters an environment where creative thinking is valued and rewarded, leading to innovative solutions and a higher level of student satisfaction. (Kongkhen & Chatwattana, 2023) the freedom to explore and experiment within PBL projects helps students develop a creative mindset that is essential for adapting to the rapidly changing demands of the modern world. Despite its numerous benefits, the implementation of PBL is not without challenges (Shih & Tsai, 2017). Furthermore, (Benzer & Şahin, 2013) indicates that successful PBL requires careful planning, adequate resources, and professional development for teachers to effectively facilitate student learning. Moreover, assessment of PBL outcomes can be complex, as traditional testing methods may not fully capture the breadth of skills developed through this approach (Parno et al., 2020). Nonetheless, the growing body of evidence supporting the positive impact of PBL on student skills underscores the need for its integration into mainstream education.

In conclusion, Project-Based Learning represents a transformative approach to education that aligns with the demands of the 21st century. By fostering critical thinking, collaboration, communication, and creativity, PBL equips students with the essential skills needed for success in an increasingly complex world. As educational institutions continue to seek ways to improve student outcomes, the adoption of PBL offers a promising pathway to empower students and prepare them for the future.

### 1.1 Students Skill

Project-Based Learning (PBL) significantly enhances students' critical thinking and problem-solving skills (Hung et al., 2012). Therefore, in PBL, students are presented with complex, real-world problems that lack straightforward solutions. They must research, hypothesize, test, and revise their ideas. (Pinho-Lopes & Macedo, 2014) this iterative process encourages deep analysis and evaluation of information, fostering the ability to think critically. Through this, students develop the ability to approach problems systematically and think innovatively (Setemen et al., 2023). In addition, (Solida & Amir, 2023) PBL promotes collaboration by requiring students to work in teams. They must communicate effectively, delegate tasks, and resolve conflicts, mirroring the collaborative nature of the modern workplace. This teamwork develops interpersonal skills and the ability to work harmoniously with others. For instance, (Viana et al., 2019) in a project to create a marketing plan for a new product, students must share ideas, give and receive feedback, and integrate diverse perspectives to develop a cohesive plan. Furthermore, Effective communication is a cornerstone of PBL. As the previous explanation by (Alemneh & Gebrie, 2024) students must present their findings, whether through written reports, presentations, or digital media. This practice enhances both verbal and written communication skills. (Umar & Ko, 2022) regularly presenting to peers and teachers helps students learn to articulate their thoughts clearly and confidently. In summary, Project-Based Learning (PBL) not only enhances critical thinking and problem-solving skills but also promotes collaboration and effective communication, preparing students for the complexities and demands of the modern workplace.

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PBL fosters creativity by encouraging students to think outside the box and explore multiple solutions. (Zhang & Hwang, 2023) the open-ended nature of projects allows for innovative thinking and experimentation. For instance, a project on creating a prototype for an eco-friendly product pushes students to brainstorm and implement unique ideas, thus nurturing their creative abilities. (Abuhmaid, 2020) through PBL, students learn to manage their time and resources efficiently. This enhances their organizational skills and self-discipline such as managing a long-term project on researching and presenting solutions to local environmental issues requires students to create timelines, meet deadlines, and ensure that all team members contribute effectively. Furthermore, (Mosier et al., 2016) Project-Based Learning involves tackling complex, open-ended problems that require students to go beyond rote memorization. By engaging with real-world issues, students must analyze, evaluate, and synthesize information from multiple sources (Sarwi et al., 2021). Therefore, this deep engagement fosters critical thinking. (Faozi et al., 2020) PBL emphasizes the application of theoretical knowledge to practical situations. Students learn to connect academic concepts with real-world applications, enhancing their problem-solving skills. (Karan & Brown, 2022) this process strengthens their problem-solving abilities by requiring them to apply abstract knowledge in concrete scenarios. In addition, (Muzana et al., 2021) PBL projects often mirror real-world professional environments where teamwork is essential. Students work in groups to achieve common goals, necessitating effective communication, role assignment, and conflict resolution. For instance, in a project to develop a marketing strategy for a new product. Thus, this teaching methods can foster creativity, critical thinking, organizational skills, and effective teamwork, equipping students with the practical skills and innovative mindset needed to tackle real-world challenges.

Through collaborative projects, students develop strong interpersonal skills (Chen & Chan, 2021). Therefore, students can learn to listen actively, express their ideas clearly, and provide constructive feedback. These skills are critical in both academic and professional settings. In addition, (Kartini et al., 2021) this project provides students with the freedom to explore multiple solutions to problems, fostering creativity and innovation. By encouraging students to think outside the box and experiment with different approaches, PBL nurtures a creative mindset. (Jewpanich & Piriyasurawong, 2015) PBL often involves integrating knowledge from various disciplines, encouraging students to approach problems from multiple perspectives. Thus, this project method interdisciplinary approach fosters creative thinking by highlighting the connections between different fields of study.

In summary, Project-Based Learning is a transformative educational approach that significantly enhances student skills across multiple domains. By engaging students in real-world problems, promoting collaboration, fostering creativity, and developing critical thinking and communication skills, PBL prepares students for the demands of the modern world. The emphasis on self-management, responsibility, and real-world relevance further ensures that students are not only equipped with essential skills but are also motivated and engaged learners. As educational institutions continue to seek ways to improve student outcomes, the integration of PBL offers a promising pathway to empower students and prepare them for future success.

### 1.1 Students Motivation

One of the primary ways Project-Based Learning (PBL) enhances student motivation is by making learning relevant to real-world issues (Hung et al., 2012). When students work on projects that address real-life problems, they see the direct application and importance of their academic efforts. This relevance makes learning more meaningful and engaging (Kılıç, 2022). In other words, (Wanglang & Chatwattana, 2023) PBL provides students with authentic learning experiences that mirror real-life scenarios and challenges. These authentic tasks enhance motivation by showing students the value and applicability of their learning (Jeon et al., 2014). For instance, a project that involves creating a business plan for a startup gives students a hands-on experience with for example entrepreneurship atc. In addition, (Kassem, 2018) PBL increases student motivation by connecting learning to real-world contexts. PBL helps students achieve a sense of mastery and competence (Mustapha et al., 2020). As they progress through their projects, they build and apply new skills, leading to a sense of accomplishment.

Furthermore, the collaborative nature of PBL also enhances motivation through social interaction (Retno et al., 2019). This collaborative environment makes learning more enjoyable and less isolating. For instance, collaborating on a science fair project not only deepens scientific understanding but also strengthens friendships and peer networks (Plailek et al., 2023). Continuous feedback and reflection are integral to PBL, contributing to sustained motivation (Rini et al., 2020). In other words, regular feedback from teachers and peers helps students understand their progress and areas for improvement. Reflecting on their learning experiences enables students to appreciate their growth and set future goals.

Project-Based Learning offers a dynamic and engaging approach to education that significantly enhances student skills and motivation as (Kassem, 2018) declared therefore (Hadi & Izzah, 2019) by focusing on real-world problems, encouraging collaboration, and providing opportunities for creativity and autonomy, PBL prepares students for the demands of the modern world. The skills developed through critical thinking, problem-solving, communication, collaboration, and creativity are essential for success in both academic and professional settings (Kök & Duman, 2023). Furthermore, the intrinsic motivation fostered through PBL ensures that students are not only prepared for future challenges but are also enthusiastic and engaged learners.

In conclusion, (Widarbowo et al., 2023) Project-Based Learning is a highly effective educational approach that significantly enhances student motivation by connecting learning to real-world issues, providing autonomy and choice, fostering a sense of mastery and competence, promoting collaboration and social interaction, offering continuous feedback and reflection, and demonstrating real-world impact and recognition. In addition, by creating a learning environment that is engaging, relevant, and supportive, PBL motivates students to take ownership of

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their learning, pursue their interests, and achieve their goals. In other words, this heightened motivation not only improves academic outcomes but also prepares students for lifelong learning and success in their future careers.

## 2. METHOD

This study employs a meta-analysis method. The purpose of this meta-analysis is to combine, review, and summarize findings from two or more previous studies. The population for this study consists of journal articles indexed in Scopus and accredited by Sinta, published in the last 10 years, and discussing the effectiveness of project-based learning in enhancing student skills and motivation. The sample for this study includes 13 journals that meet the criteria of providing outcome data in the form of means and standard deviations. The data analysis technique involves calculating the effect size of each journal and then statistically analyzing these to determine the overall effect of project-based learning on student skills and motivation. The data analysis process involves calculating the effect size for each journal and subsequently conducting a statistical analysis to determine the overall impact of project-based learning on student skills and motivation. In addition, the data analysis technique utilizes JASP software. Thus, this meta-analysis provides a comprehensive review of the effectiveness of project-based learning, demonstrating its significant positive impact on enhancing student skills and motivation over the past decade.

**Table 1 – Metadata of the Studies Included**

| No. | Studies | N | Location | Sample Characteristic | Variable 1 | Variable 2 | Mean | SE |
|---|---|---|---|---|---|---|---|---|
| 1. | (Jalinus et al., 2019) | 20 | Indonesia | University | PjBL | Skill | 3.91 | 0.15563 |
| 2. | (Kiong et al., 2022) | 38 | Malaysia | Teacher | PjBL | Skill | 4.15 | 0.14437 |
| 3.. | (Kiong et al., 2022) | 102 | Malaysia | Teacher | PjBL | Skill | 3.94 | 0.06931 |
| 4.. | (Jewpanich & Piriyasurawong, 2015) | 9 | Thailand | University | PjBL | Skill | 4.44 | 0.27000 |
| 5. | (Plailek et al., 2023) | 30 | Thailand | University | PjBL | Skill | 4.64 | 0.90557 |
| 19. | (Kongkhen & Chatwattana, 2023) | 7 | Thailand | University | PjBL | Skill | 4.74 | 0.15874 |
| 11. | (Wanglang & Chatwattana, 2023) | 7 | Thailand | Teacher | PjBL | Skill | 4.50 | 0.18520 |
| 12. | (Syahril et al., 2021) | 51 | Indonesia | University | PjBL | Soft Skill | 4.46 | 0.08588 |
| 13. | (Jeon et al., 2014) | 55 | Korea | University | PjBL | Motivation | 3.25 | 0.07108 |
| 14. | (Shih & Tsai, 2017) | 67 | Taiwan | University | PjBL | Skill and Motivation | 3.98 | 0.08918 |
| 15. | (Abuhmaid, 2020) | 247 | Korea | University | PjBL | Skill | 3.87 | 0.00950 |
| 16. | (Mustapha et al., 2020) | 166 | Malaysia | University | PjBL | Skill | 3.36 | 0.09377 |
| 17. | (Ayish & Deveci, 2019) | 124 | Abu Dhabi | University | PjBL | Skill | 3.57 | 0.00641 |
| 18. | (Mosier et al., 2016) | 6 | Australia | High School | PjBL | Skill | 3.45 | 0.0020 |

The presented table is a summary of 13 journals that examine the implementation of Project-Based Learning (PjBL) and its impact on various educational variables such as skills, soft skills, and motivation. This table includes important information such as the authors and publication year of the journals, sample size (N), research location, sample characteristics, variables studied, mean values, and standard errors (SE). These studies were conducted in various countries, including Indonesia, Malaysia, Thailand, Korea, Taiwan, Abu Dhabi, and Australia, with sample characteristics ranging from university students to teachers and high school students.

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## 3. RESULTS AND DISCUSSION

### *Results*

The results of this analysis include 13 articles indexed by Scopus and accredited by Sinta which has 18 studies.

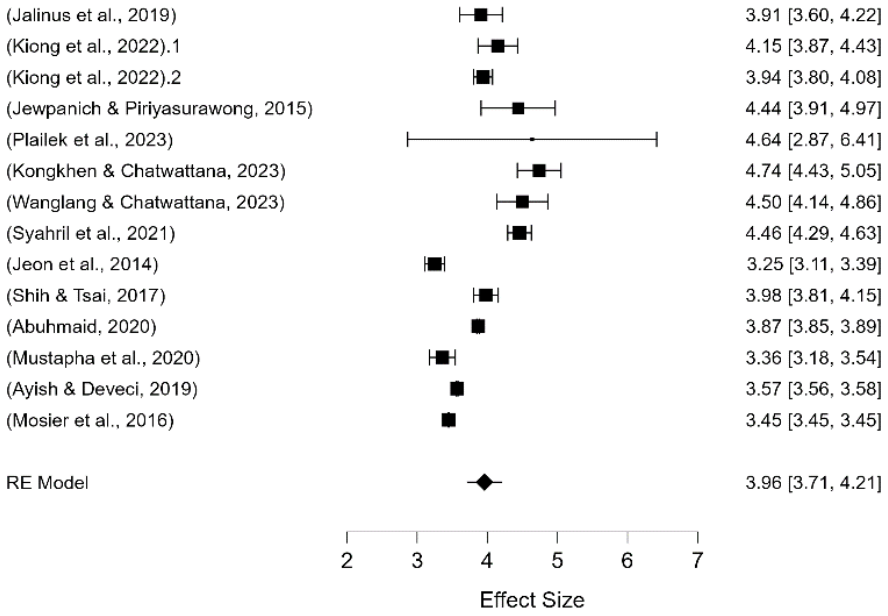


Figure 1. Forest Plot of the Project-Based Learning studies

This study collected and analyzed data from various studies to assess effect sizes in the researched context. The forest plot displays the results of 14 individual studies, each with varying effect sizes. These studies span different years and research contexts, as indicated by references such as Jalinas et al. (2019), Kiong et al. (2022).1, Kiong et al. (2022).2, Jewpanich & Piriyasurawong (2015), Plailek et al. (2023), Kongkhen & Chatwattana (2023), Wanglang & Chatwattana (2023), Syahril et al. (2021), Jeon et al. (2014), Shih & Tsai (2017), Abuhmaid (2020), Mustapha et al. (2020), Ayish & Deveci (2019), and Mosier et al. (2016).

The effect sizes of each study are represented by black squares, where the size of each square indicates the weight or contribution of the respective study to the meta-analysis. The horizontal lines passing through each square represent the 95% confidence intervals for the effect sizes. For example, the study by Jalinas et al. (2019) shows an effect size of 3.91 with a confidence interval of [3.60, 4.22], while the study by Kiong et al. (2022).1 shows an effect size of 4.15 with a confidence interval of [3.87, 4.43]. This variation indicates that despite differences in methodology and study populations, there is a clear trend in the measured effect sizes.

At the bottom of the graph, the diamond symbol represents the combined estimate from all studies using a random effects model. This combined effect size is 3.96 with a 95% confidence interval of [3.71, 4.21]. These results indicate that overall, the effect sizes produced by these studies are consistent and statistically significant, with a confidence level that the true effect size lies between 3.71 and 4.21.

The heterogeneity among these studies can be observed from the varying effect sizes and confidence intervals, indicating differences in methodology, populations, or other factors affecting the results of each study. Nonetheless, the combined results from this meta-analysis provide strong evidence of a significant effect across the various research contexts analyzed.

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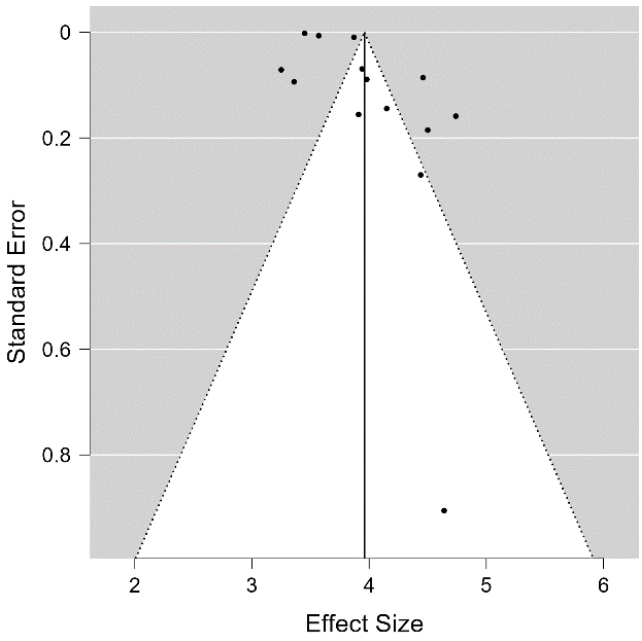


Figure 1. Funnel Plot of the Project-Based Learning Studies

The funnel plot in this study was used to assess potential publication bias in the meta-analysis. In this plot, effect size is displayed on the horizontal axis (x-axis) and standard error on the vertical axis (y-axis). Each dot on the plot represents the results of an individual study included in the analysis. In an ideal funnel plot, where there is no publication bias, the dots would be symmetrically dispersed around the vertical line representing the combined effect size, forming a symmetric inverted funnel shape.

From the analysis of this plot, it can be seen that most of the dots are dispersed around the vertical line with an effect size of about 4, indicating relatively good symmetry. This suggests that publication bias is not significant in this set of studies, as the symmetrical distribution shows that the results from smaller studies (with higher standard errors) tend to be consistent with the results from larger studies. However, several dots are outside the funnel boundaries, particularly at the lower part of the plot. These dots indicate the presence of study variation or high heterogeneity, which could be due to differences in methodology, study populations, or other factors affecting the results of each study. The presence of these outlying dots highlights the need for further evaluation of the methodology and quality of these studies to understand the sources of variation.

Therefore, this funnel plot shows a fairly symmetric distribution, indicating that publication bias may not be significant in this set of studies. However, the presence of some dots outside the funnel boundaries suggests variations in methodology or study quality, warranting further attention in the interpretation of the meta-analysis results. These results provide confidence that the conclusions derived from this meta-analysis are robust and not overly influenced by publication bias, although inter-study variation still needs to be considered.

***Discussion***

The visual representation through the forest plot effectively illustrates the range of effect sizes across studies, cantering around a consistent overall impact, which underscores the strength of PBL interventions despite variations in research settings. However, a clearer explanation of how to interpret the size and direction of the individual study effects, as well as their confidence intervals, would enhance reader comprehension. The funnel plot, used to assess publication bias, appears relatively symmetrical, indicating minimal bias, yet further clarification on the interpretation of asymmetries and the meaning of outlier studies would strengthen the analysis. In addition, beyond the statistical findings, the study's implications for teaching should be more prominently emphasized particularly how PBL's proven benefits can be translated into curriculum design, teacher training, and classroom practice. Moreover, while the presence of heterogeneity is acknowledged, a more in depth analysis of its sources such as differences in students populations, instructional contexts, and implementation fidely would provide richer insights and guide future implementation and research.

Furthermore, the forest plot showed that individual effect sizes varied but generally centered around a combined effect size of 3.96, with a 95% confidence interval of [3.71, 4.21]. This consistency across studies suggests a robust overall effect, reinforcing the validity of the meta-analysis. Despite methodological and population differences among the studies, the central tendency observed in the effect sizes points to a common underlying effect, which is both statistically significant and consistent. The funnel plot analysis was crucial in evaluating potential publication bias. Ideally, in the absence of such bias, the plot would display a symmetrical inverted funnel shape. In this study, the funnel plot revealed a relatively symmetrical distribution of the effect sizes around the combined effect size, suggesting minimal publication bias. The symmetry indicates that smaller studies with higher standard errors yielded results consistent with larger studies, further validating the robustness of the meta-analysis.

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However, some studies were positioned outside the funnel boundaries, particularly towards the lower end of the plot. These outliers indicate potential heterogeneity among the included studies, which could stem from various sources such as differences in research design, sample characteristics, intervention implementations, and measurement tools. This observed heterogeneity underscores the importance of interpreting the combined effect size with consideration of the diverse contexts and methodologies of the individual studies. According to educational experts, project-based learning (Jeon et al., 2014) has been shown to significantly enhance student capabilities and motivation. For instance, John Larmer, editor at the Buck Institute for Education, highlights that PBL engages students in real-world problem-solving, fostering critical thinking and collaboration skills. Similarly, a report by (Viana et al., 2019) found that PBL can lead to higher student achievement and greater engagement compared to traditional teaching methods.

The findings of this meta-analysis align with these expert opinions. The robust combined effect size and the consistent results across various studies provide strong evidence that PBL is an effective instructional strategy. By engaging students in meaningful projects, PBL not only enhances their academic skills but also boosts their motivation to learn, as they see the relevance and application of their studies to real-world scenarios (Kassem, 2018). The presence of heterogeneity, as indicated by the variation in effect sizes and confidence intervals, suggests that while the overall effect is significant, there are underlying differences that need to be acknowledged. Factors contributing to this heterogeneity could include variations in the study settings, participant demographics, and specific implementation of PBL. Recognizing and addressing these differences is essential for understanding the broader applicability of the findings. A significant strength of this meta-analysis is its comprehensive inclusion of studies from diverse contexts, providing a robust and generalizable combined effect size. Additionally, the use of both forest and funnel plots enhances the reliability of the findings by visually assessing consistency and potential biases. However, limitations must be acknowledged. The presence of outliers in the funnel plot suggests that some degree of heterogeneity exists, which could affect the interpretation of the combined effect size. Furthermore, the analysis is dependent on the quality and reporting standards of the included studies. Variations in study quality could contribute to the observed heterogeneity, and future research should aim to standardize methodologies to minimize these differences.

The effectiveness of Project Based Learning (PBL) in the educational context has been proven through various studies showing significant improvements in multiple educational aspects (Setiyadi et al., 2024). PBL offers students the opportunity to actively engage in the learning process through projects that are relevant to real life. This method allows students to develop critical thinking, problem-solving, and collaboration skills (Rini et al., 2020). Furthermore, (Karan & Brown, 2022) and (Benzer & Şahin, 2013) PBL encourages deeper learning as students must thoroughly understand concepts to complete their projects. In terms of motivation, PBL has also been shown to be effective because students feel more motivated when they see a direct connection between what they are learning and its practical application (Kassem, 2018). In other words, PBL can reduce the achievement gap among students from different backgrounds, as this method tends to be more inclusive and adaptive to various learning styles.

In conclusion, this meta-analysis provides strong evidence of a significant and consistent effect of project-based learning on student capabilities and motivation, with minimal indication of publication bias. The findings are robust, yet the observed heterogeneity highlights the need for careful interpretation considering the diverse contexts of the included studies. (Puangpunsi, 2021) and (Syawaludin et al., 2022) emphasizing the benefits of PBL in enhancing student engagement and achievement. Future research should focus on standardizing methodologies and exploring the sources of heterogeneity to enhance the generalizability and applicability of meta-analytic findings. This study contributes to the existing body of literature by consolidating evidence across multiple studies, offering valuable insights into the overall effect and its implications in educational contexts.

## 4. CONCLUSION

This study, through meta-analysis, provides strong evidence that project-based learning has a significant and consistent effect on enhancing students' abilities and motivation. Of the 14 studies analyzed, the combined effect size was found to be 3.96 with a 95% confidence interval between [3.71, 4.21]. These results indicate that PBL is an effective and reliable teaching strategy that not only improves students' academic skills but also motivates them to study more diligently. The funnel plot analysis also showed that publication bias is not significant in this set of studies, indicated by the symmetrical distribution of points around the vertical line on the plot. However, the variation found in some studies suggests the presence of heterogeneity, caused by differences in methodology, study populations, or other factors. Nevertheless, the main findings still show that PBL has a consistently positive effect.

These results strengthen the argument that PBL should be more widely implemented in educational curricula at various levels. By involving students in real-world projects, PBL can enhance critical thinking, collaboration, and problem-solving skills that are highly needed in today's workforce. Educators and policymakers should consider integrating PBL into educational programs, providing the necessary training and resources for teachers to effectively implement this method. Well-trained teachers in PBL methods will be more capable of facilitating meaningful and relevant learning for students.Teachers must receive proper training to effectively implement PBL. This includes understanding how to design relevant and engaging projects, as well as how to assess student learning outcomes within the context of projects. Continuous professional development for teachers is crucial to ensure they have the latest skills and knowledge to successfully implement PBL. Additionally, this training will help

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teachers address challenges and overcome obstacles that may arise during the implementation of PBL in the classroom.

In addition, to enhance the practical utility of the findings, this study recommends specific strategies for implementing PBL effectively in classroom settings. Moreover, schools should provide sustained professional development focused on project planning, assessment strategies, and the use of digital tools to support PBL. Therefore, this study introduces selection bias despite minimal indication of publication bias in the funnel plot. Additionally, variability in this study quality, contextual differences in PBL implementation, and inconsistent measurement of outcomes contribute to heterogeneity and should be addressed in future research. Although this meta-analysis shows the positive effects of PBL, further research is needed to identify the factors contributing to the observed heterogeneity. Future research should focus on standardizing methodologies and measurements to ensure more consistent results. Longitudinal studies can help understand the long-term impacts of PBL on student learning outcomes and how this method can be applied in different educational contexts. Curricula should be designed to better support the PBL approach, with flexibility that allows students to explore topics in-depth through projects they choose themselves. Curricula supporting PBL should also include tools and technologies that enable student collaboration and creativity, as well as assessment methods that emphasize the learning process in addition to the final results.

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## APPENDICES

Lampiran 1. Fixed Random Effect

**Fixed and Random Effects**

| | Q | df | p |
|---|---|---|---|
| Omnibus test of Model Coefficients | 942.795 | 1 | < .001 |
| Test of Residual Heterogeneity | 2460.748 | 13 | < .001 |

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

Lampiran 2. Coefficient

**Coefficients**

| | | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | Estimate | Standard Error | z | p | Lower | Upper |
| intercept | 3.960 | 0.129 | 30.705 | < .001 | 3.707 | 4.213 |

*Note.* Wald test.

Lampiran 3. Residual Heterogeneity Estimates

**Residual Heterogeneity Estimates**

| | | 95% Confidence Interval | |
|---|---|---|---|
| | Estimate | Lower | Upper |
| $\tau^2$ | 0.205 | 0.095 | 0.559 |
| $\tau$ | 0.453 | 0.309 | 0.748 |
| $I^2$ (%) | 99.903 | 99.793 | 99.965 |
| $H^2$ | 1035.981 | 482.936 | 2823.472 |

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