Two Decades of Project-Based Learning in Engineering Education: A 21-Year Meta-Analysis

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***Abstract* – The implementation of project-based learning (PjBL) has contributed to improving students' learning outcomes. However, strong evidence specifically linking PjBL to the improvement of students' higher-order thinking skills (HOTS) is still limited, especially in engineering education. Hence, this study aims to uncover the impact of PjBL on students' HOTS through a meta-analysis. A total of 16 studies were sourced from ACM, Dimensions, IEEE, Science Direct, Scopus, and WOB metadata, with a search time ranging from 2003 to 2023. Data sourced from relevant literature were analyzed using a random-effects hedge model in JASP software. The results showed that the application of PjBL had a significant impact, rRE (0.315), or 31.5% on students' HOTS in the context of engineering education. Furthermore, there was no publication bias in the analysis of the studies. Meanwhile, the review of moderator variables showed that PjBL is most frequently implemented in Eastern cultures, particularly in computer science subjects, and the most common method for measuring skills is through test scores. Generally, the integration of PjBL into the learning process could effectively improve students' HOTS.**

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1. Introduction

Engineering education is an educational institution that specifically prepares individuals for professional careers that demand specialized technical expertise [1], [2]. This education acts as a catalyst in shaping students into skilled globally competitive businesses and industries.

In various countries, engineering education is known by different terms. In Spain, it is referred to as "Educación en Ingeniería". In Italy, it is called "Educazione in Ingegneria". Meanwhile, in Germany, the terms used is "Ingenieurausbildung." In Japan, it is referred to as "Enjiniaaringu Kyouiku." In Indonesia, engineering education is often termed as "Pendidikan/Sekolah Kejuruan". However, the objectives of these various terms allude to the same goal, to equip students with specialized competencies in preparation for the workforce [3].

There are several majors or fields within engineering education, such as automotive engineering, electrical engineering, electronics engineering, and civil engineering. One of the most relevant characteristics across all engineering fields is that the majority of learning is conducted through practical work [6]. Students must have practical skills based on academic theories. Therefore, they must be able to balance practical skills and academic abilities to achieve optimal results in their learning.

In line with achieving good learning outcomes, students are also required to have multi-skills. As engineering students, they must engage in critical thinking to analyze what they are learning. They should be able to collaborate and work together in teams to create and develop projects in their field of study.They must be capable of solving problems logically to analyze potential challenges that may arise.

They must also be able to abstract and execute logical thinking algorithms to solve problems quickly and accurately, as well as be resilient and able to consider the long-term impact of each step taken. All of these skills are multi-capabilities, critical thinking, analytical, teamwork, collaboration, computation, creativity and problem solving. If students are able to apply them, it means they have higher-order thinking skills (HOTS) [7], [8]. To achieve this goal, appropriate learning methods need to be applied. One of the most popular and relevant learning methods for this purpose is project-based learning (PjBL). PjBL is highly suitable as a learning method because much of its process involves direct immersion in the field to produce a product [9].

Students are required to further enhance their HOTS. They must be able to balance hard skills, soft skills, cognitive knowledge, and professional skills [10], [11]. This cannot be achieved through traditional learning methods, like memorization, note-taking, and the absence of practical application of the knowledge learned. As a result, students' knowledge remains purely theoretical. In enhancing the quality of education to accommodate students' skills, governments in various countries have implemented many strategies, including incorporating diverse learning models into the curriculum [12]. These strategies range from simple adjustments, modifying students' learning styles through differentiated learning, to more complex ones, like changing teaching methods by integrating learning applications and allocating more time for practical sessions, particularly through the implementation of project-based learning (PjBL). These changes are driven by the increasing demands of industries and the rapidly evolving technological advancements, necessitating students to learn more than ever before [13], [14]. PjBL helps students balance academic or theoretical knowledge with practical applications, as well as provides an understanding of the necessity of both hard skills and soft skills as professional students through carefully designed projects [15], [16]. Furthermore, PjBL utilizes projects as its medium, providing a final learning outcome in the form of projects that serve as a measure of students' skill attainment. Therefore, PjBL not only focuses on the end product but also serves as a platform where students can balance the practical and academic skills they learn.

In the automotive engineering field, students will design and develop a mini car prototype, which involves planning, material testing, and suspension design.

In the electrical and electronics engineering field, they will work on projects such as automatic control devices, smart home systems, and monitoring.

The stages include identifying needs, component selection, programming, testing, and maintenance. Additionally, in civil engineering, students will engage in projects related to the design, construction, and maintenance of physical infrastructure such as buildings, bridges, roads, and water systems. The process involves needs analysis, design planning, material selection, construction and implementation, as well as maintenance and improvement.

Several studies have reported that PjBL has contributed to students' learning development [17], [18]. This development is done through integration with the respective subjects of study, especially those related to practicum. Despite the widespread implementation of PjBL and many studies examining its outcomes, strong evidence specifically linking PBL to HOTS improvement is still limited. Most studies mainly focus on learning outcomes in general but less on students' HOTS [6]. By systematically reviewing and synthesizing findings with statistical formulas from studies conducted over the past 21 years, this study aims to provide an evaluation of the effectiveness of PBL in promoting students' HOTS and to identify areas where further empirical investigation is needed. Additionally, this study aims to recommend to educational institution stakeholders the consideration of long-term technologies that are relevant to students' abilities. Thus, its meta-analysis addresses the evidence gaps in existing research on the impact of PBL on the development of students' (HOTS) in engineering education. Furthermore, the application of local culture and the selection of skill achievement measures should also be carefully considered. To achieve this objective, the following research questions were formulated:

1. **RQ1.** How does the application of project-based learning influence the improvement of students' higher-order thinking skills in engineering education?
2. **RQ2**. How is the impact of the moderator on project-based learning and students' higher-order thinking skills?

1.1. Literature Review

Project-based learning (PjBL) became popular in the late two decades as educators realized the need for a shift in the transfer of learning from traditional methods to those that more actively engage students' cognitive development [19]. Guo [20], revealed in his study that PjBL refers to instructional learning that engages students more actively in reconstructing knowledge through meaningful products or projects in line with their real-world environment.

This aligns with teachers' expectations that students need to transition from passive receivers of information to active learners capable of applying knowledge in the real world.

PjBL has six main characteristics, including: triggering students' curiosity to generate questions, making students active in projects, focusing on students' goals and achievements, promoting cooperation among team members, creating artifacts relevant to the current era, and utilizing advanced technology [21]. In the initial stage of project introduction by teachers, students will be given project guidelines that encourage them to ask questions and explore [23]. Throughout the learning process, they will continue to develop knowledge gradually. Unconsciously, their critical thinking abilities will be further trained, understanding of the topic will increase, and their analytical skills will be well honed. Additionally, the learning process will be tailored by the teacher by forming students into groups. They will be divided into several teams to practice cooperation and collaboration among members. Each group member will have their own tasks to be completed within the allocated time, thus they have the responsibility to successfully complete the project. Lastly, this process is inseparable from the use of technology. Essentially, technology will facilitate work in planning, implementation, and outcomes [24], [25]. Ultimately, students will be able to produce a product whose artifact can be evaluated as a measure of success. Through this process, students go through the creation of a new product. In this process, students apply higher-order thinking skills (HOTS). Therefore, it can be concluded that the process of the PjBL learning method cannot be separated from students' HOTS.

2. Method

A meta-analysis was used in this study, which included three main processes.

First, the research objectives were formulated. This is important as a guide for the entire review process, ensuring that the literature search is focused and relevant. A well-defined research objective not only clarifies the scope of the review but also helps in identifying specific parts of PjBL in engineering education. Second, collecting and identifying scientific publications related to the topic under study. This involved selecting appropriate databases, keywords, and inclusion or exclusion criteria. The systematic nature of this process ensured that all relevant literature was considered, thus increasing the robustness of the reliable review. Third, interpreting the data collected and uncovering findings related to the research questions.

2.1. Data Collection

This meta-analysis study involves collecting various articles and deriving conclusions based on statistical formulas. The primary objective was to investigate the effectiveness of PjBL in improving students' HOTS within the context of engineering education. All publications were gathered from ACM, Dimensions, IEEE, Science Direct, Scopus, and WOB metadata using the keywords "project-based learning" AND "engineering education". The collected data consisted of research articles published from 2003 to 2023.

2.2. Inclusion Criteria

The search for articles was conducted using exclusion criteria, which focused on articles that did not meet specific requirements. The inclusion criteria, on the other hand, were articles that aligned with predetermined requirements and research objectives [26]. The criteria for analysis can be found in Table 1.

Table 1. Inclusion criteria

Criteria	**Description**
Field	Articles topic is the application of PjBL in engineering education
Publication year	2003-2023
Design	Publication with control and experimental groups
Instrument	Publication with pre-test and post-test information
Language	English
Data	Sample size (N), mean (M), and standard deviation (SD)

The PRISMA method as outlined by Samala [27], was utilized in this study and comprised four stages: identification, screening, eligibility, and inclusion.

The results of the data identification process can be seen in Figure 1.

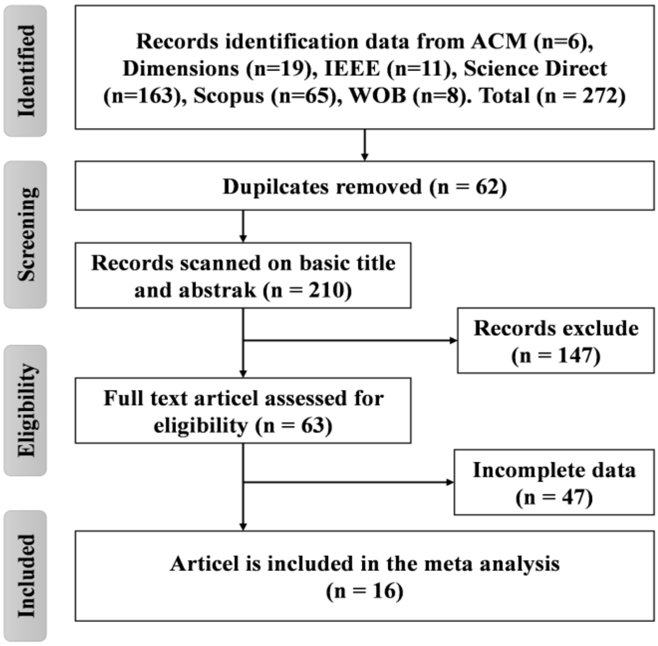

Figure 1. Research procedures using the PRISMA method

3. Data Analysis

Following data collection based on the inclusion criteria, an analysis was perfomed using the random-effects hedge meta-analysis method, with the assistance of JASP software. Before the analysis, the dataset contained information on sample size (N), mean (M), and standard deviation (SD). The initial analysis involved utilizing Microsoft Excel to extract additional details regarding the effect size and standard error. To calculate the results for the effect size and standard error, the following mathematical formula was applied.

$$g = \frac{x_e + x_c}{\sqrt{\frac{(n_e-1)\,Se^2 + (n_c-1)\,Sc^2}{n-2}}} \qquad (1)$$

$$SEg = \sqrt{\left(\frac{n_e+n_c}{n_e.n_c}\right) + \frac{g^2}{2(n-2)}} \qquad (2)$$

Description:
g = effect size
Seg = standar error
xe and *xc* = mean of experimental and control group
Se and *Sc* = standar deviation of experimental and control group
n, ne and *nc* = total of samples, and number of samples in the experimental and control group.

Subsequently, a keyword analysis of the relevant literature was conducted using VOSviewer software. The purpose of this analysis was to find research trends, key topics, and relationships between concepts from the development of PjBL over the past 21 years.

4. Results

Based on the results displayed in the PRISMA procedure (Figure 1), there were 272 publications from ACM, Dimensions, IEEE, Science Direct, Scopus. There were 62 publications with similarities that were excluded as duplicate documents. Following this, further screening was conducted by reviewing titles and abstracts, resulting in the exclusion of publications that were less relevant to the topic and objectives of this study. After the title and abstract screening process, 63 publications were checked for data completeness. These publications were required to contain data such as sample size (N), mean (M), and standard deviation (SD). The final screening yielded 16 publications eligible for inclusion in the meta-analysis study.

Upon completing the review process of the 16 selected publications, which included identification, screening, assessment of eligibility, and inclusion, these 16 publications were chosen for this meta-analysis study. Data from the selected publications are summarized in Table 2, providing an overview of the characteristics and main variables of the included studies.

Table 2. Data recapitulation

Study	Author (year)	Experiment Group			Control Group			g	SEg
		N	M	SD	N	M	SD		
1	Anih and Ukeh, 2023, [28]	74	40,09	5,11	62	38,59	4,89	0,3	0,17
2	Lidan and Salleh, 2023, [29]	40	32,37	12,56	40	22,91	13,57	0,72	0,23
3	T. S. Chang et al., 2022, [30]	19	52,2	5,73	23	47	5,48	0,91	0,32
4	Cortázar et al., 2021, [31]	421	61,43	18,58	413	58,32	19,41	0,16	0,07
5	Younis et al., 2021, [32]	123	4,12	0,17	124	4,02	0,23	0,49	0,13
6	L. L. Wu et al., 2021, [33]	140	4,06	0,82	20	3,21	1,21	0,97	0,24
7	Chen et al., 2022, [34]	18	32,14	5,25	18	36,28	6,4	-0,69	0,34
8	Mursid et al., 2022, [35]	40	83,3	3,67	40	80	3,54	0,91	0,23
9	Ridlo, et al., 2020, [36]	30	51,45	8,04	35	51,38	6,73	0,01	0,25
10	Barak and Dori, 2005, [37]	95	30,14	18,64	120	31,82	19,2	-0,09	0,14
11	Chung, G. K. 2003, [38]	25	1,78	0,43	25	1,63	0,32	0,39	0,28
12	C. C. Chang et al, 2011, [39]	30	77,36	13,14	30	74,79	13,13	0,19	0,26
13	Bagheri et al., 2020, [40]	38	153,3	12,8	40	151,6	15,1	0,12	0,23
14	Stolk and Martello, 2015, [41]	38	4,08	0,98	38	3,93	1,09	0,14	0,23
15	Baran, et al., 2018, [42]	21	3,45	1,61	13	3,54	1,56	-0,05	0,35
16	H. Y. Wang et al., 2014, [43]	48	4,04	0,35	43	3,89	0,36	0,42	0,21

Table 2 contains data extracted from the analyzed articles, providing information about sample size (N), mean (M), and standard deviation (SD) for the experimental and control groups, along with effect size (g) and standard error (SEg) for each article. This dataset facilitates comprehensive analysis to determine whether the implementation of PjBL in the experimental group yields statistically significant effects compared to the absence of PjBL in the control group. The data obtained from the Microsoft Excel analysis, including effect sizes and standard error values, serve as the main dataset for further meta-analysis using the JASP software. The primary goal is to measure the magnitude of the impact of PjBL on student higher-order thinking skills.

3.1. Summary Effect

RQ 1: How does the application of project-based learning influence the improvement of students' higher-order thinking skills in engineering education?

The purpose of the summary effect size is to offer an estimate of the average effect of an intervention or the relationship between variables across all research samples that have been analyzed.

This summary effect size serves as a consolidated measure that captures the overall impact or association observed in the collective body of research [44], [45].

In this study, a random effects model was employed to investigate whether there existed a significant positive correlation between implementing PjBL and enhancing students' higher-order thinking skills engineering education.

The analyses are presented in Table 3.

Table 3. Summary effect test

Estimate	SE	z	p	95% Confidence Interval Lower	Upper
0.315	0.096	3.282	< .001	0.127	0.502

Based on Table 3, the random effects model indicates a significant positive correlation between the application of PjBL and the improvement of students' HOTS (z=3.442; p<0.001; 95% CI [0.127–0.096]). The magnitude of the influence of PjBL and the improvement of students' HOTS falls within the low category (rRE=0.315), at 31.5%. This interpretation is based on Cohen's classification [46] where a correlation coefficient of 0.1 is considered low, 0.5 medium, and 0.8 high. A forest plot illustrating these findings is presented in Figure 2.

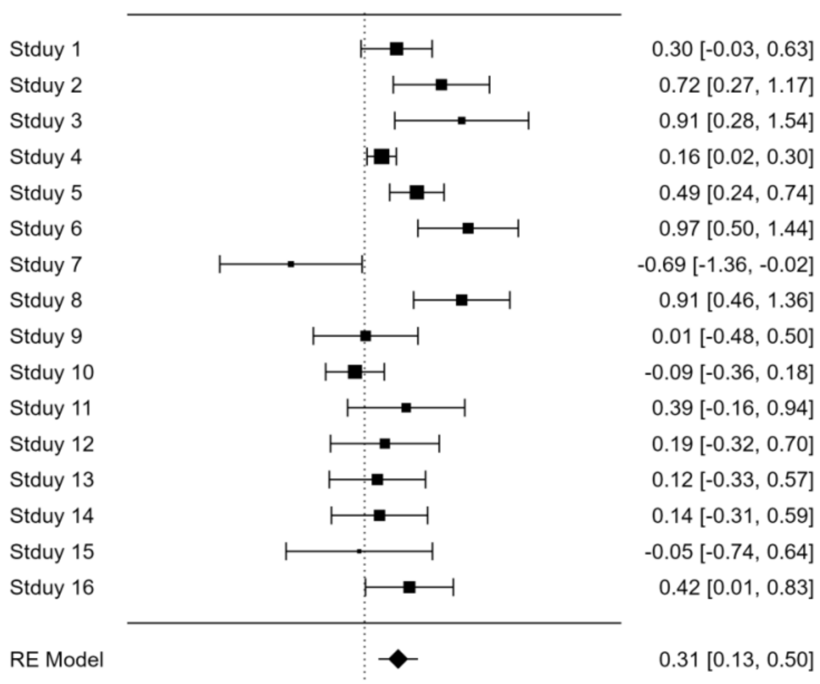

Figure 2. Forest plot

From the results presented in Figure 2, 16 studies are grouped based on Cohen's significance criteria. It was found that 12 studies fall into the low significance category, 1 studies fall into the medium category, and 3 studies fall into the high significance category. Fig. 2 indicates that the influence of project-based learning on students' higher-order thinking skills in engineering education is estimated to be 0.31 or 31%.

This suggests that approximately 31% of the variation in students' higher-order thinking skills can be attributed to the use of project-based learning in engineering education.

3.1 Publication Bias

The funnel plot (Figure 3), Edger's regresion, and fail safe-N were used to assess publication bias.

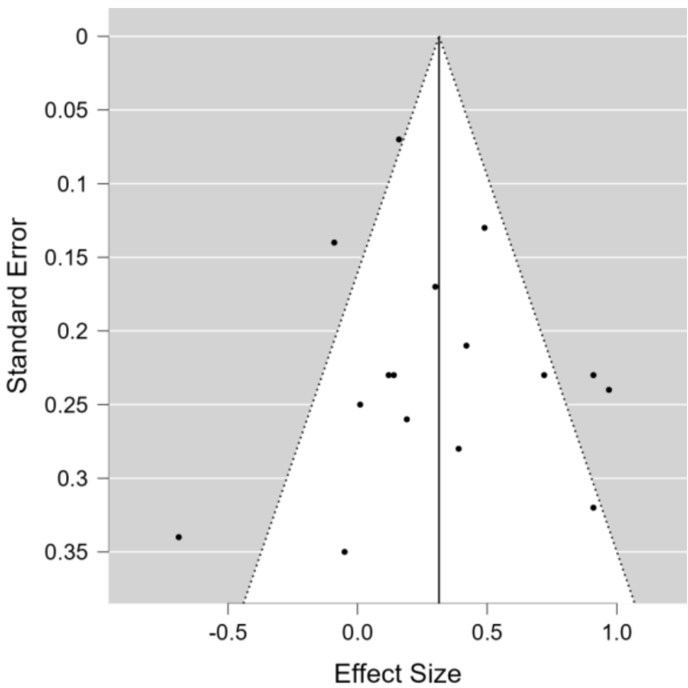

Figure 3. Funnel plot

Figure 3 shows that the funnel plot generated from the analysis tended to be symmetric [47].

The distribution of the analyzed studies was even, showing no publication bias in meta-analysis.

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Fail-safe N and Edger's Test was conducted to further complement and improve the comprehensiveness of data. The test results are shown in Table 4.

Table 4. Summary effect test

Fail-safe N	Target significance	Observed significance	Edger's test
202.000	0.050	< 0.001	0.922

In meta-analysis studies, there is the term publication bias. This term is defined as a phenomenon where research results are statistically unlikely to be published, because it can result in distortions in scientific work. Therefore, there are certain criteria in determining the potential for publication bias. The first is fail-safe N. The fail-safe N criterion is N > 5k + 10, where k is the number of publications analyzed [48]. In this study, the number of publications is 16 (k = 16), so the calculation is 5(16) + 10 = 90. While the analysis results from the JASP software show that N = 202 > 90, with a significance level of 0.05 and p < 0.001, it can be concluded that the first criterion has been met which indicates that there is no publication bias from the analyzed study. In addition, there is a second criterion, namely Edger regresion. This criterion is used to complement and enhance the cohesiveness of the data. The Edger Regresion is a test conducted to detect the significance level of potential bias of the analyzed study. This method provides a p value that indicates whether there is any asymmetry in the distribution of effect sizes that could indicate bias. If the p test result > 0.05, it can be said that there is no evidence of bias in the publication [49]. The analysis of 16 studies showed that the p value is 0.922. So it can be concluded that there is no significant publication bias in these meta-analysis studies.

3.2. Moderator Analysis

RQ2. How is the impact of the moderator on project-based learning and students' higher-order thinking skills?

This meta-analysis study is examining the impact of project-based learning (PjBL) on students' higher-order thinking skills (HOTS), moderators are often used to understand whether the observed outcomes vary based on certain external variables [50], [51]. Three moderating factors were selected: culture (Eastern and Western), fields, and skill measure.

The culture factor refers to culture differences that may influence the impact of PjBL on students' HOTS.

In this study, culture is divided into two categories: Western and Eastern.

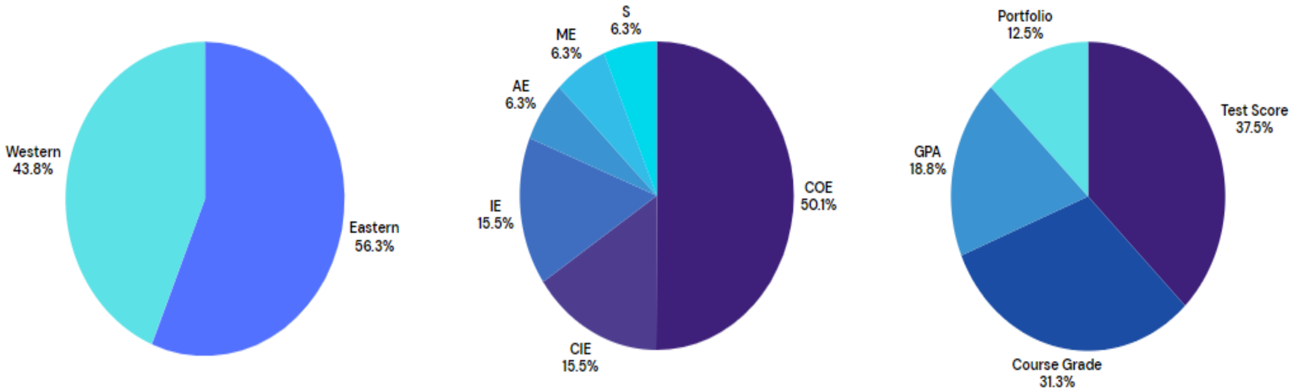
This factor can lead to variations in culture, education systems, resources, and policies that can affect the effectiveness of PjBL. Meanwhile, the fields factor refers to different subjects or fields of study where PjBL is applied, such as computer science, STEM, and basic engineering. The impact of PjBL on students' HOTS may vary depending on the subject being taught. Lastly, we analysis meassure skill to determine its effectiveness in assessing the outcomes of project-based learning. Each of these methods provides a different perspective on students' abilities in their respective fields of study. By analyzing these three moderating factors, researchers can gain a deeper understanding of the conditions that affect the effectiveness of PjBL in enhancing students' HOTS. This also helps identify variations in outcomes based on external factors, providing valuable insights for educational planners and teachers.

Table 5. Moderator variable

Study	Country	Field	Skill measure
1	Nigeria	Computer engineering	Test score
2	China	Computer engineering	Course grade
3	Taiwan	Civil Engineering	Course grade
4	Chile	Computer engineering	Course grade
5	USA	Computer engineering	GPA
6	USA	Automotive engineering	Test score
7	Taiwan	Industrial engineering	Test score
8	Indonesia	Mechanical engineering	Course grade
9	Indonesia	STEM	Test score
10	USA	Chemistry engineering	GPA
11	USA	Civil engineering	GPA
12	Taiwan	Computer engineering	Portfolio
13	Iran	Computer engineering	Test score
14	USA	Computer engineering	Course grade
15	Turkey	Industrial engineering	Test score
16	Taiwan	Computer engineering	Portfolio

In this study, the countries where the research was conducted were divided into two cultural categories: Eastern (China, Taiwan, Indonesia, Iran, Turkey), and Western (Nigeria, Chile, USA). From the data presented (Table 5), it can be seen that the countries that have most extensively implemented PjBL are those with Eastern cultures.

Additionally, PjBL has been applied in various fields of engineering, particularly in computer engineering. Finally, the most commonly used measure of improvement in HOTS in the articles selected for this study is test scores. The interpretation of this data is presented in the visualization in Figure 4.



a). Culture *b). Field* *c). Skill masure*

Figure 4. Moderator analysis

COE = Computer engineering
CIE = Civil Engineering
IE = Industrial engineering
AE = Automotive engineering
ME = Mechanical engineering
S = STEM

The data in Figure 4 reveals that although the USA is the country with the highest frequency of PjBL implementation, when categorized by culture, Eastern countries exert the most significant influence, accounting for 56.3%. This suggests that despite the prevalence of PjBL in the USA, Eastern cultural contexts have embraced and applied this pedagogical approach more extensively. In terms of fields, computer engineering emerges as the most influenced, with over 50% prevalence. This indicates a strong inclination towards implementing PjBL within the realm of computer engineering compared to other fields.

Furthermore, concerning the measure of skill, test scores emerge as the most influential, estimated at 37.5%. This underscores the importance placed on assessing the effectiveness of PjBL through standardized testing measures, highlighting its impact on students' higher-order thinking skills.

4. Discussion

PjBL has been applied in various countries in engineering education over the past 21 years. This widespread adoption showcases its growing importance and relevance in the field. In the context of this meta-analysis, the keyword analysis provided additional insights into the dynamics of PjBL at global level. The articles showed a trend of increasing application of technology in learning projects, supporting the results of significant changes in PjBL over the past twenty one years.

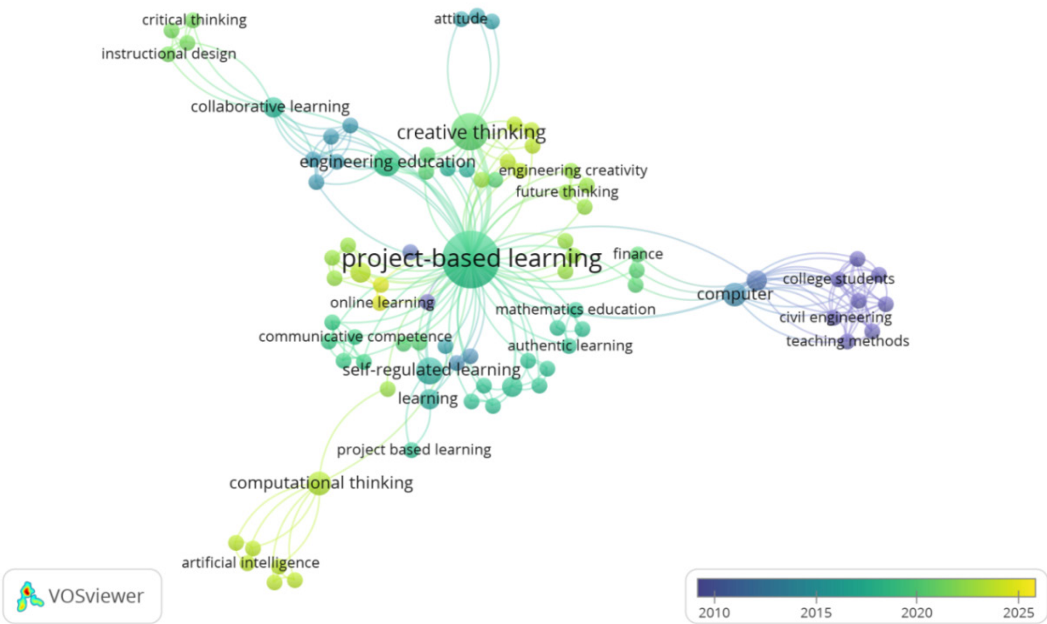


Figure 5. Tren of PjBL

Figure 5 shows that the term "project-based learning" (PjBL) was mostly mentioned. It also shows the close relationship between PjBL and engineering education, along with other components such as critical thinking, creative thinking, computational thinking, and teamwork or collborative, which were included in HOTS section. The figure also shows the trend of topics discussed from 2010 to 2025, indicating that recent developments have reached the prevalence of artificial intelligence and online learning. This trend supports the assertion that PjBL is closely related to the development of students' HOTS, where critical, creative, and computational thinking skills are essential for creating valuable products. Artificial intelligence (AI) and online learning can enhance PjBL by providing tools and platforms that support the learning process [52], [53]. In engineering education, many subjects cannot be explained abstractly; with the help of AI, these subjects can become more concrete and tangible. Additionally, AI can offer faster feedback, while online learning enables access to resources and collaboration across geographical boundaries.

Improving students' HOTS, including critical thinking, creative thinking, computational thinking, and teamwork or collborative, could be effectively achieved through the application of PjBL [54]. The approach offered students a more practical and contextualized learning experience by including students in real projects. HOTS also corresponded with 21st-century skills, where students were required to have 6C skills (critical thinking, creativity, communication, collaboration, citizenship, and character) [55].

Firstly, critical thinking refers to the ability to critically analyze, assess, synthesize information, and make decisions based on deep understanding. Secondly, creativity pertains to the ability to think creatively, generate new ideas, and solve problems in innovative ways. Thirdly, communication focuses on the ability to convey ideas and information clearly and effectively, both orally and in writing, using a variety of media. Students can also directly consult with experts, making learning process more engaging. Fourthly, collaboration is the ability to collectively and effectively in teams achieve common objectives [22]. Fifthly, citizenship focuses on the ability to understand and appreciate diversity, and actively participate in both local and global societies with social responsibility. Lastly, character encompasses politeness, sensitivity to the environment and surroundings, integrity, ethics, responsibility, and empathy to form a strong and ethical personality. This is the type of character needed by the industry today. In fact, most companies highly consider employees with good ethics and honesty, as these traits create a positive and productive work environment, ultimately contributing to the company's success.

Additionally, the analysis of moderator variables indicates that Western countries may face challenges in integrating PjBL, but collectivist values can be advantageous in PjBL implementation [56]. Conversely, Eastern countries tend to be more receptive to PBL due to alignment with cultural values emphasizing innovation and autonomy, as seen in countries like China and Taiwan experiencing rapid growth in technology and industry [57].

This evidence provides insight into how culture influences PjBL implementation and can guide teachers in adapting teaching methods to local cultural contexts. On the other hand, there are significant trends based on fields of study: information technology emerges as the dominant discipline significantly influenced by PjBL. This dominance leads educators to adopt PjBL more extensively in IT education [4]. Additionally, the flexibility of this approach across various educational settings suggests that PjBL can enhance students' higher-order thinking skills. Lastly, in measuring skill achievement, the most influential factor is test scores, contributing 37.5%. This evidence evaluates the effectiveness of PjBL through standardized testing procedures. Besides assessing the products created by students, end-of-learning tests also serve as significant indicators of students' skill achievement.

The results of meta-analysis showed that PjBL had a positive and effective impact on improving students' thinking skills compared to not implementing PjBL. The application of the method offered a broader exploration experience to develop learning concepts, particularly when supported by various technologies that could improve students' knowledge and cognitive abilities. Through the application of PjBL, students were expected to be better equipped to face the constantly evolving global challenges. Furthermore, the role of professional teachers was crucial in integrating technology into learning process.

The meta-analysis results of this study have filled the information gap by proving that PjBL has a positive and significant impact on improving students' thinking skills in engineering education. The application of this learning method provides students with the opportunity to explore learning concepts more broadly, bridge the gap between theoretical and practical knowledge, and develop both hard and soft skills, especially with the support of various technologies [5]. The use of technology can improve the overall quality of education. Teachers who are proficient and professional in adopting technology will guide the success of the learning process, especially in implementing PjBL, because the role of the teacher cannot be replaced by technology. Therefore, teachers have a very important role in integrating technology for the success and advancement of PjBL in education.

5. Conclusion

The conducted meta-analysis has proven that PjBL supports the effectiveness of enhancing students' higher-order thinking skills (HOTS) in engineering, with a significant positive effect size of 0.315.

This indicates that PjBL contributes approximately 31.5% to the development of students' higher-order thinking skills. Besides the direct impact of PjBL, this study also revealed the role of moderators in influencing outcomes. Cultural factors, such as the Eastern culture exemplified by China and Taiwan, demonstrate success in their education systems, providing inspiration for other countries to maximize the implementation of PjBL. Additionally, technological fields, particularly computer technology, and assessment methods, such as exam scores, were identified as the most influential moderators. This suggests the importance of considering local culture in the learning process as a distinctive characteristic of a country. Furthermore, careful consideration should also be given to the selection of student skill achievement measures.

To further refine these findings, future research is recommended to explore external factors such as technological support and grade levels to determine which factors truly play a role or contribute to enhancing the impact of PBL on students' higher-order thinking skills.

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