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The Effectiveness of Project-Based Learning Model in Physics Learning: A Bibliometric Study

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ABSTRACT

This study aims to identify annual publication trends, the most productive countries and institutions, influential authors and journals, dominant themes, and the thematic evolution of Project-Based Learning (PjBL) research in physics education during 2020-2025, addressing the lack of a comprehensive, up-to-date bibliometric mapping in this field. This study used a descriptive quantitative approach through a systematic literature review (SLR) supported by bibliometric analysis. Data were retrieved from the Scopus database and filtered using the keywords (project-based learning OR pjbl) AND (physic OR physics learning OR physics education), yielding 298 documents, which were further narrowed to 156 documents (2020-2025) as the basis for bibliometric analysis using VOSviewer, while the five most highly cited documents were examined in depth through the SLR. The results show a significant increase in publications since 2023, peaking in 2024, with Indonesia as the leading contributing country and a keyword network indicating strong integration among PjBL, physics education, STEM, educational technology, and critical thinking skills; however, cross-country collaboration remains weak and fragmented. This study offers novelty as the first comprehensive bibliometric mapping specifically focused on the effectiveness of PjBL in physics education for the most recent period, integrated with in-depth empirical evidence from the SLR, providing a foundation for strengthening the theoretical framework and future research directions in this field.

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INTRODUCTION

21st-century education has driven a shift from conventional, teacher-centered learning models toward active, student-centered approaches, in line with growing demands for critical thinking, collaboration, and problem-solving competencies. Scholarly attention to STEM education continues to grow, as evidenced by bibliometric analyses of thousands of articles indexed in Web of Science, which reveal citation patterns, author productivity, institutional contributions, and keyword networks that have expanded rapidly over the past decade. This shift has also been driven by the rapid advancement of technology in the Industry 4.0 era, which has likewise influenced the field of education, including the integration of technology-based learning media (Mastuang et al., 2025).

Physics remains one of the subjects most frequently perceived as difficult by students, as it requires analyzing and visualizing phenomena based on logic interpreted through formulas and symbolic calculations, while the difficulty of imagining such phenomena without direct experience makes physics seem confusing, resulting in relatively low student learning interest (Abdul Razaq & Diyana, 2023), as cited in Jurnal Inovasi Penelitian dan Pembelajaran Fisika. A similar issue has been confirmed for other fundamental physics concepts; one study found that university students still experience misconceptions about motion and force, particularly in analyzing the relationship between an object's mass and acceleration and in understanding the direction of gravitational force (Nurwahidah, 2022). A comparable issue has also been confirmed regarding the concept of Black's Principle, which is often taught abstractly without an experimental approach, making it difficult for students to relate the concept to their real-world experience (Masara et al., 2024). In response to these challenges, Project-Based Learning (PjBL) has long been proposed as an alternative learning model that enables students to construct understanding through direct

engagement in real-world projects, and this model has been shown to effectively engage students in more active and meaningful learning (Almulla, 2020). The literature also confirms that the implementation of PjBL within the context of STEM education is consistently associated with improved higher-order thinking skills and students' conceptual understanding (Diana et al., 2021).

Several recent empirical studies confirm the effectiveness of PjBL in physics education. A quasi-experimental study involving 150 physics students across three universities showed that PjBL significantly improved conceptual understanding, problem-solving ability, practical competence, engagement, and student motivation (Wang et al., 2025). Other studies found that the implementation of PjBL contributes to improving students' higher-order thinking skills (HOTS) in science subjects, particularly in the physics domain (Khaeruddin et al., 2023), while PjBL among gifted physics students has been shown to fulfill the preconditions for learning engagement, namely challenge, competence, and curiosity (Makkonen et al., 2021). Even at the secondary school level, the implementation of context-based media through PjBL has been shown to enhance students' learning creativity (Emafri et al., 2020).

This growing body of evidence on effectiveness is consistent with a surge in the volume of publications related to PjBL across various educational levels and science education contexts, as an instructional approach that promotes active participation, including at the secondary school level (McKinney, 2023). However, this rapid growth in the literature also presents a new challenge: mapping the direction, intellectual structure, and thematic trends of research through conventional narrative reviews alone. Conventional systematic reviews and meta-analyses generally focus on synthesizing outcomes from a selected number of studies, making them effective in answering the question of whether PjBL is effective, but less capable of mapping author productivity patterns, cross-country collaboration networks, thematic evolution over time, or the intellectual structure of the field in a quantitative and visual manner. The bibliometric approach emerges to fill this gap, as it is able to reveal citation patterns, author productivity, institutional and country contributions, as well as keyword co-occurrence networks systematically and based on large-scale data (Khalil et al., 2024).

Several bibliometric studies on related or even identical topics have been conducted. A bibliometric study of 100 articles selected from 449 documents in Scopus (2020-2024) on blended learning in science education found that author distribution remains dominated by the United States and Indonesia (Mastuang et al., 2025). More specifically on the topic of PjBL in physics, (Farkhan et al., 2025)**,** conducted a bibliometric review using Scopus data and found that, of the 48 publications analyzed, the number of publications actually declined over the past three years after peaking in 2021, which is presumed to be related to the challenges of implementing PjBL during the COVID-19 pandemic; this study also revealed that a number of institutions and countries have not yet actively contributed to this topic. A similar mapping effort was also conducted by (Anasi & Harjunowibowo, 2023), who analyzed research trends of PjBL in physics teaching over the past ten years, as well as by (Weganofa et al., 2022), who mapped the broader development trends of PjBL research.

Although these three studies provide important contributions as a foundation for mapping the PjBL literature in physics, each has limitations. (Farkhan et al., 2025), analyzed only 48 publications, resulting in a relatively small scope that may not fully capture the latest developments in the literature; the study by (Anasi & Harjunowibowo, 2023) focused on a ten year time span without specifically highlighting the issue of PjBL effectiveness; while (Weganofa et al., 2022) examined PjBL more generally across disciplines without focusing on the context of physics education. Thus, no bibliometric study has yet been found that specifically and comprehensively maps the effectiveness of PjBL implementation in physics education during the most recent period (2020-2025), encompassing productivity trends, cross country/institutional collaboration, intellectual structure, and thematic evolution in an integrated manner using a broader dataset. Based on this gap, this study aims to identify annual publication trends, the most productive countries and institutions, the most influential authors and journals, dominant themes/keywords, and the evolution of research focus on PjBL in physics education through a bibliometric analysis based on the Scopus database for the 2020-2025 period, which is expected to contribute both methodologically and practically to the development of evidence-based physics education policy and practice.

RESEARCH METHOD

This study uses a descriptive quantitative analysis technique, implemented through a Systematic Literature Review (SLR) supported by bibliometric analysis. Within this design, the SLR serves as the overarching method for identifying, screening, and synthesizing relevant literature, while bibliometric analysis functions as a supporting analytical tool used to quantitatively describe the characteristics of the

literature set, such as publication volume, temporal trends, collaboration patterns, and conceptual structure through keyword co-occurrence.

The bibliometric component draws on secondary data in the form of scientific publication metadata as the unit of analysis, rather than primary data collected directly from research participants (Ninkov et al., 2022). Unlike experimental or survey-based research that examines cause-and-effect relationships or individual perceptions, this descriptive quantitative technique aims to systematically map the patterns, trends, and intellectual structure of a field of study through statistical description of previously published literature. This descriptive quantitative analysis is applied to all documents that passed the year-filtering stage (2020-2025), to examine publication volume, temporal trends, collaboration networks, and conceptual relationships (keyword co-occurrence) related to the implementation of Project-Based Learning (PjBL) in physics education. The bibliometric mapping in this stage is not treated as a separate, equally weighted track, but as an analytical instrument embedded within the SLR process, providing the quantitative descriptive foundation before the study narrows to a more focused narrative synthesis of a small number of the most highly cited documents. This narrower synthesis describes, in depth, the concrete empirical evidence regarding the effectiveness of PjBL in physics education, evidence that cannot be captured through descriptive/bibliometric mapping alone. Figure 1 illustrates the overall research design adopted in this study:



Figure 1. Research Design

This study uses the SLR instrument, supported by bibliometric techniques, to process the literature data by measuring publication trends, mapping distributions, and visualizing keyword relationships using VOSviewer (Page et al., 2021). The document selection process follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram, structuring the identification, screening, and eligibility stages according to the research topic. Data were collected from the Scopus database through the following stages: the initial identification yielded 49,797 documents; after filtering using the keywords in the title–abstract–keyword field (project-based learning OR project based learning OR pjbl) AND (physic OR physics learning OR physics education), 298 documents were obtained; after further filtering based on the 2020-2025 time range, 156 documents remained. From this point, the descriptive quantitative (bibliometric-assisted) analysis proceeds in two sequential stages within the single SLR framework:

a. Descriptive quantitative mapping stage: all 156 documents are used to statistically describe annual publication trends, productive countries and institutions, authorship networks, and keyword co-occurrence mapping carried out with the assistance of bibliometric software (VOSviewer).
b. In-depth SLR synthesis stage: from these 156 documents, an eligibility assessment is conducted based on the highest citation performance, resulting in 5 documents that are analyzed in depth to provide a detailed narrative synthesis of the empirical findings on the effectiveness of PjBL in physics education. Figure 2 presents the document selection process using the PRISMA flow diagram:

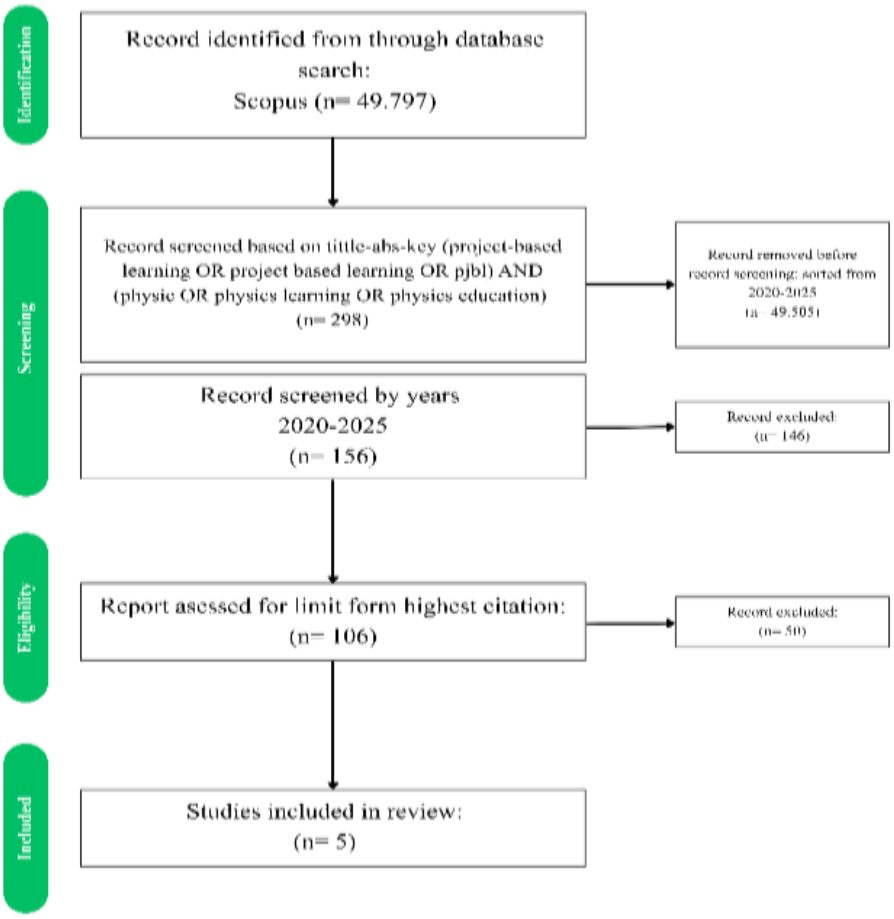


Figure 2. PRISMA Chart

Through this descriptive quantitative technique, grounded in SLR and assisted by bibliometric analysis this study produces a comprehensive mapping of document sources, leading affiliations, citation performance, contributing countries, subject areas, source titles (journals), authorship patterns, and keyword co-occurrence, together with an in-depth narrative synthesis of the empirical evidence on the effectiveness of PjBL in physics education, covering the 2020-2025 period.

RESULTS AND DISCUSSION

Results

We obtained publication trends for 2020-2025 using the keywords (project-based learning OR project based learning OR pjbl) AND (physics OR physics learning OR physics education) in the Scopus database. The initial search identified 298 documents, which were then filtered based on the 2020-2025 time range, resulting in 156 documents used as the basis for the bibliometric analysis. Figure 3 presents the distribution of publications by year. Figure 3 shows that the number of publications remained relatively stagnant in the early part of the research period, with 21 documents each in 2020, 2021, and 2022. Entering 2023, the number of publications began to increase to 29 documents, then rose further to 33 documents in 2024, the highest number during the observation period, before slightly declining to 31 documents in 2025. The 2025 data may not yet fully reflect the actual number of publications, as indexing in the Scopus database generally takes time after publication. Nevertheless, this trend indicates that research on the implementation of PjBL in physics education continues to develop and is receiving increasing attention from researchers, particularly since 2023, in line with the growing demands of 21st-century competency-based curricula that encourage the broader implementation of project-based learning. Figure 4 presents the citation trend during the 2020-2025 period. Citations increased steadily from approximately 80 in 2020 to around 95 in 2021 and 2022, then rose more sharply to roughly 160 in 2023, 190 in 2024, and 245 in 2025. Unlike the publication trend, which peaked in 2024 before slightly declining in 2025, the citation trend continued to rise throughout the entire period, suggesting that although fewer new documents were published in 2025,

earlier publications continued to accumulate citations over time a pattern consistent with the general nature of citation metrics, which tend to grow cumulatively rather than reset annually.

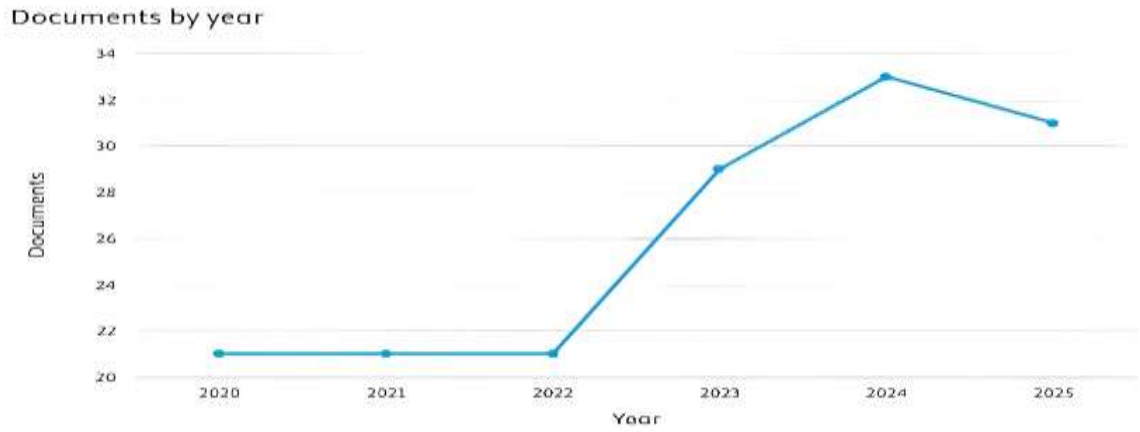


Figure 3. Document per Year

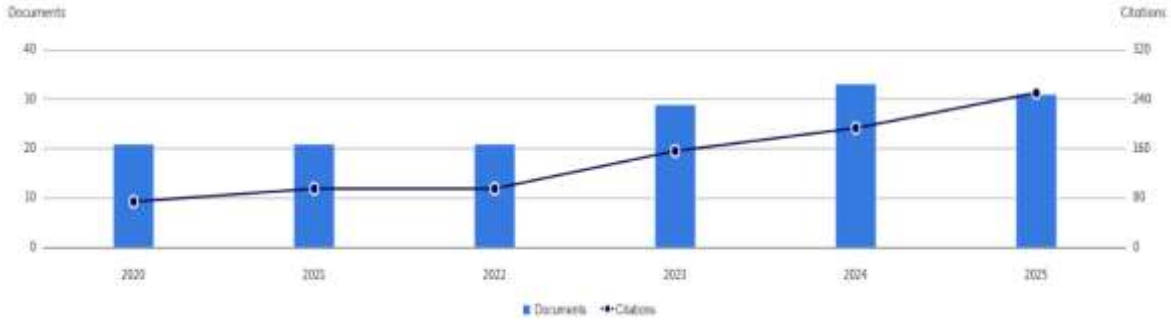


Figure 4. Citation per Year

Next, the distribution of publication source types related to PjBL in physics education is presented in Figure 5. Based on the analysis, the most dominant document type was conference papers, accounting for 44.9%, followed by articles at 44.2%, conference reviews at 7.1%, book chapters at 3.2%, and reviews at 0.6%. The near-equal dominance of conference papers and articles indicates that research findings in this field are widely disseminated through scientific conference forums. This is consistent with findings that a large proportion of publications related to technology-based PjBL originate from international conferences (Wahyudi et al., 2024), indicating that this field is developing dynamically and that researchers tend to favor conferences as a medium for disseminating the latest findings while also building collaborative networks. On the other hand, the nearly equivalent proportion of articles indicates that a substantial number of studies have advanced into scholarly works published in reputable journals through a peer review process, thereby producing findings that are more comprehensive and scientifically valid.

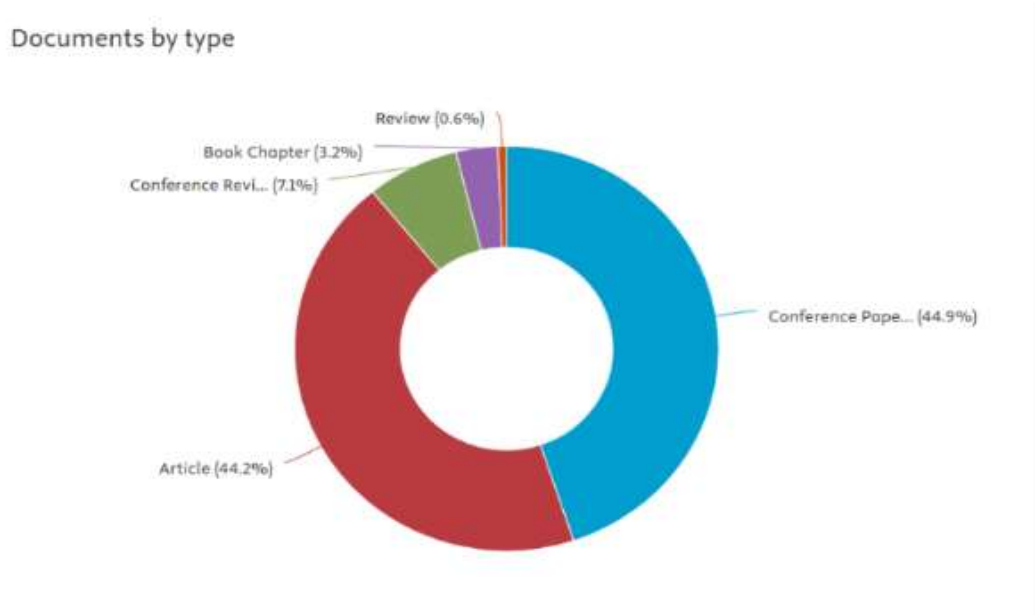


Figure 5. Document Types

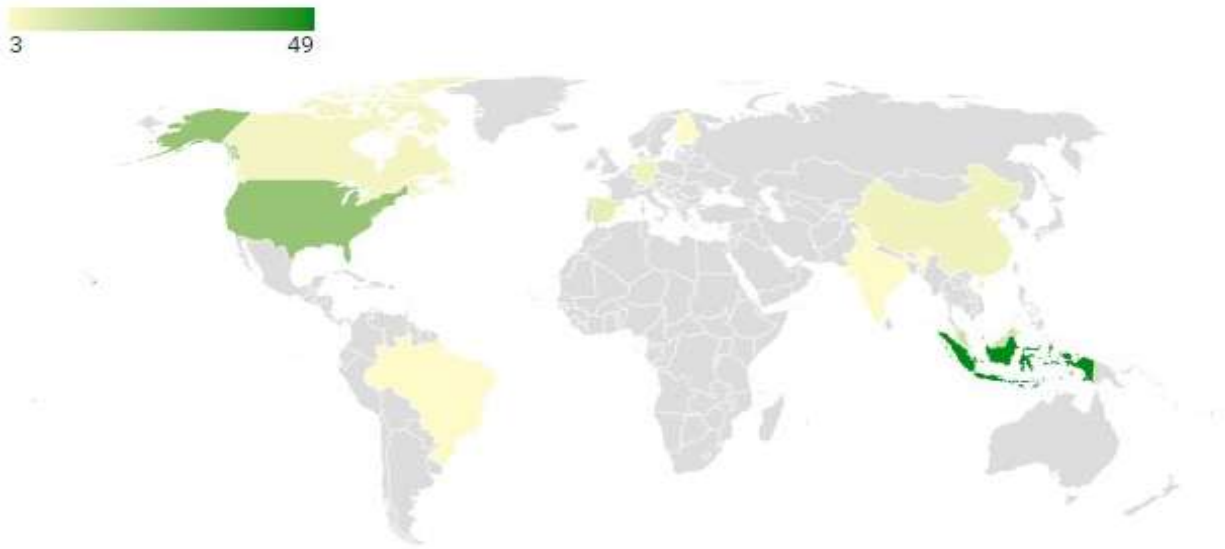


Figure 6. Top 10 Countries Contributed to Research on the Effectiveness of Project-Based Learning in Physics Education.

Figure 6 shows the ten countries with the largest publication contributions to research on the effectiveness of Project-Based Learning (PjBL) in physics education during the 2020-2025 period. Based on the analysis of Scopus data, Indonesia ranked first with 49 documents, followed by the United States (25 documents), Malaysia (13 documents), Spain (8 documents), China (6 documents), Germany (6 documents), Canada (5 documents), Brazil (3 documents), Finland (3 documents), and India (3 documents). Indonesia's high publication contribution indicates that research on implementing PjBL in physics education is actively developing in Indonesia. This finding is consistent with Nurmasyitah et al. (2025), which reported that Indonesia is among the countries with the highest publication contributions in bibliometric studies on PjBL, particularly in science education and the development of creative thinking skills. These results indicate that research on PjBL is no longer dominated solely by developed countries, but is also growing rapidly in developing countries, including Indonesia. This trend is likely related to the increasing implementation of project-based learning across education levels, as well as the growing body

of research in education focused on strengthening 21st-century skills. Figure 7 illustrates the co-authorship network among countries contributing to PjBL research in physics education.



Figure 7. Co-authorship Network of Countries in Research on the Effectiveness of Project-Based Learning in Physics Education.

Figure 7 shows the co-authorship network among countries researching the effectiveness of Project-Based Learning (PjBL) in physics education, visualized using VOSviewer. The analysis identified three collaboration clusters, each comprising several countries. The first cluster (blue) was dominated by Indonesia, the second cluster (red) by Malaysia, while the third cluster (green) consisted of the United States, Germany, and Brazil. Connecting lines (links) represent relationships between countries and indicate collaboration in scientific publications. Indonesia has a close collaborative relationship with Malaysia, while Malaysia is also connected to India, thereby serving as a bridge between countries within the collaboration network. In contrast, the United States, Germany, and Brazil form a separate collaboration group with a more limited degree of connectivity. This finding is consistent with similar bibliometric studies on PjBL, which show that Indonesia plays a leading role in publications and collaboration networks, with fairly strong connections to many other countries (Chamidah et al., 2024). Nevertheless, this study on the effectiveness of PjBL in physics education shows that the collaboration network is still dominated by a few countries and has not yet formed an extensive global network. Increased cross-country collaboration is expected to enrich research perspectives, broaden knowledge exchange, and encourage the development of innovations in Project-Based Learning-based physics education across various educational contexts. Figure 8 displays the trend in the number of publications by source over the 2020-2025 period.

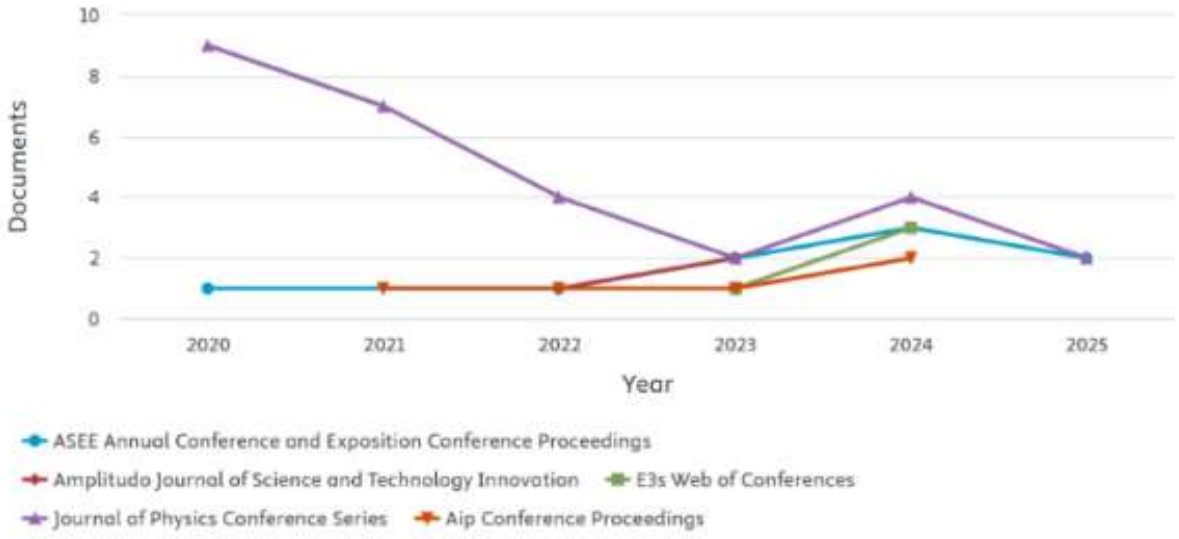


Figure 8. Documents per Year by Source on Research Related to the Effectiveness of Project-Based Learning in Physics Education (2020–2025).

Figure 8 shows the trend in the number of publications by source (documents per year by source) in research on the effectiveness of Project-Based Learning (PjBL) in physics education during the 2020-2025 period. Based on the analysis, the Journal of Physics: Conference Series was the most dominant publication source at the beginning of the research period, with 9 documents in 2020, followed by a gradual decline until 2023, a temporary increase to 4 documents in 2024, and another decline to 2 documents in 2025.

Meanwhile, the ASEE Annual Conference and Exposition Conference Proceedings, AIP Conference Proceedings, E3S Web of Conferences, and Amplitudo Journal of Science and Technology Innovation showed a relatively stable pattern between 2020 and 2022, followed by an increase during 2023-2024, before likewise declining in 2025, such that all five sources converged toward a relatively uniform number (around 2 documents). These findings indicate that publications on PjBL in physics education are no longer concentrated in a single dominant source but have begun to be distributed across various journals and scientific proceedings, although the overall number of publications per source in the final year of observation (2025) declined relative to its peak in 2024 a pattern consistent with the earlier observation that 2025 data may not yet be fully indexed in Scopus. A similar pattern has also been reported in bibliometric research on PjBL in science education, which shows that publications are becoming increasingly diverse in both source and subject scope, reflecting growing scholarly attention to implementing PjBL across various learning contexts (Wahyudi et al., 2024).

The data obtained were subsequently visualized in Figure 9, showing the results of the keyword co-occurrence mapping for the topic of project-based learning in physics education. This mapping identified several clusters, distinguished by different colors, representing interrelated themes. Among all the identified clusters, three main clusters, Cluster 1 (red), Cluster 2 (green), and Cluster 4 (purple) were selected for more in-depth discussion through zoomed-in visualizations, as these three clusters have the most direct relevance to the focus of this study, namely the implementation and effectiveness of PjBL in physics education. The remaining clusters are discussed briefly based on the overall keyword network visualization. Figures 9(a), 9(b), and 9(c) present zoomed-in visualizations of Cluster 1, Cluster 2, and Cluster 4, respectively.

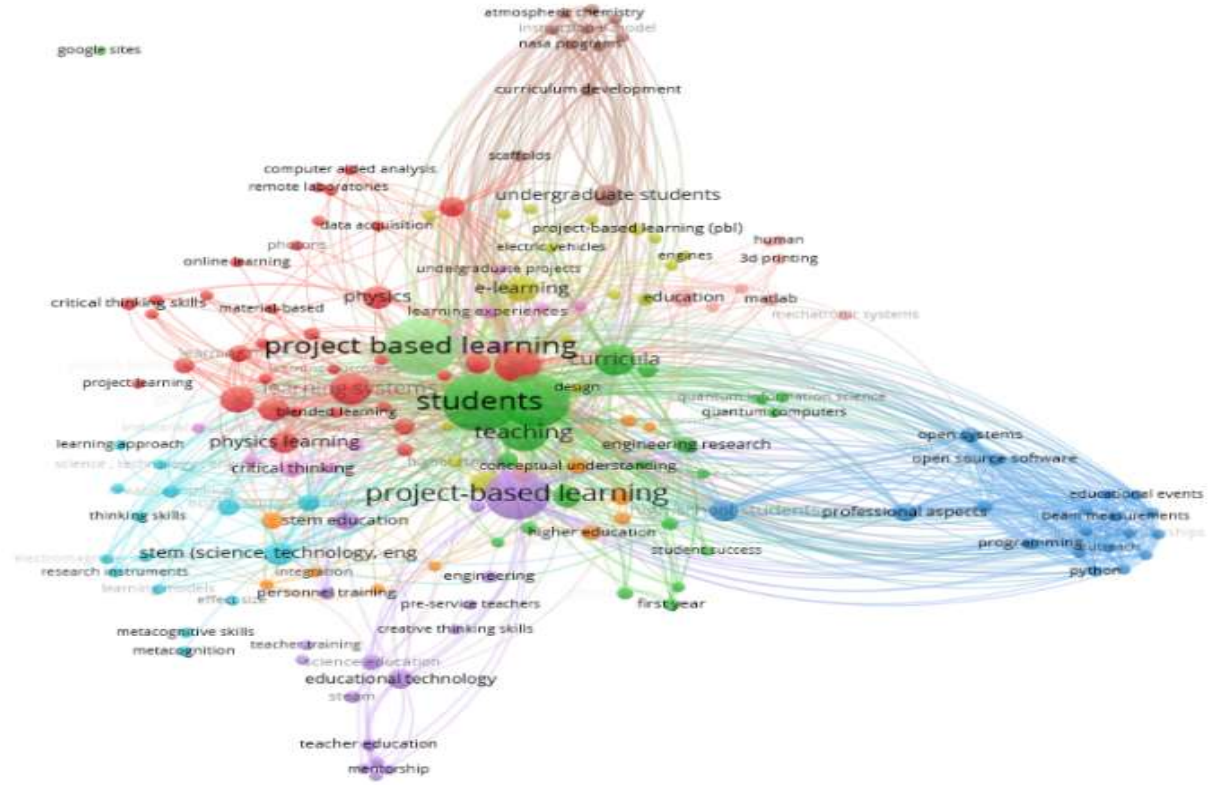


Figure 9. Keyword Co-occurrence Network Visualization

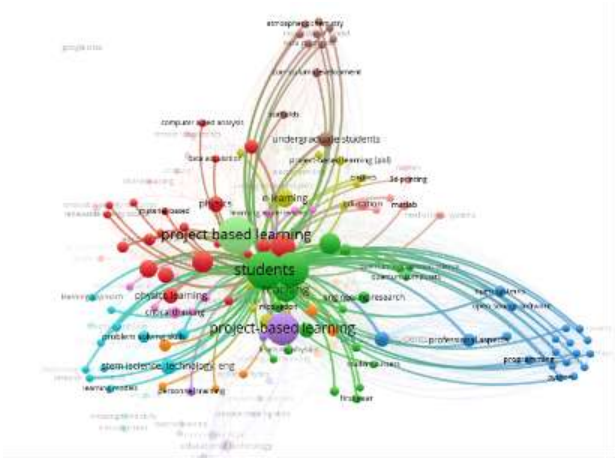


Figure 9. A

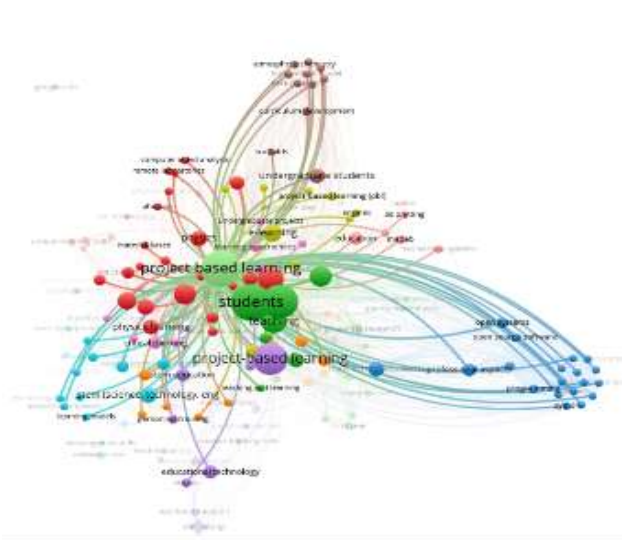


Figure 9. B

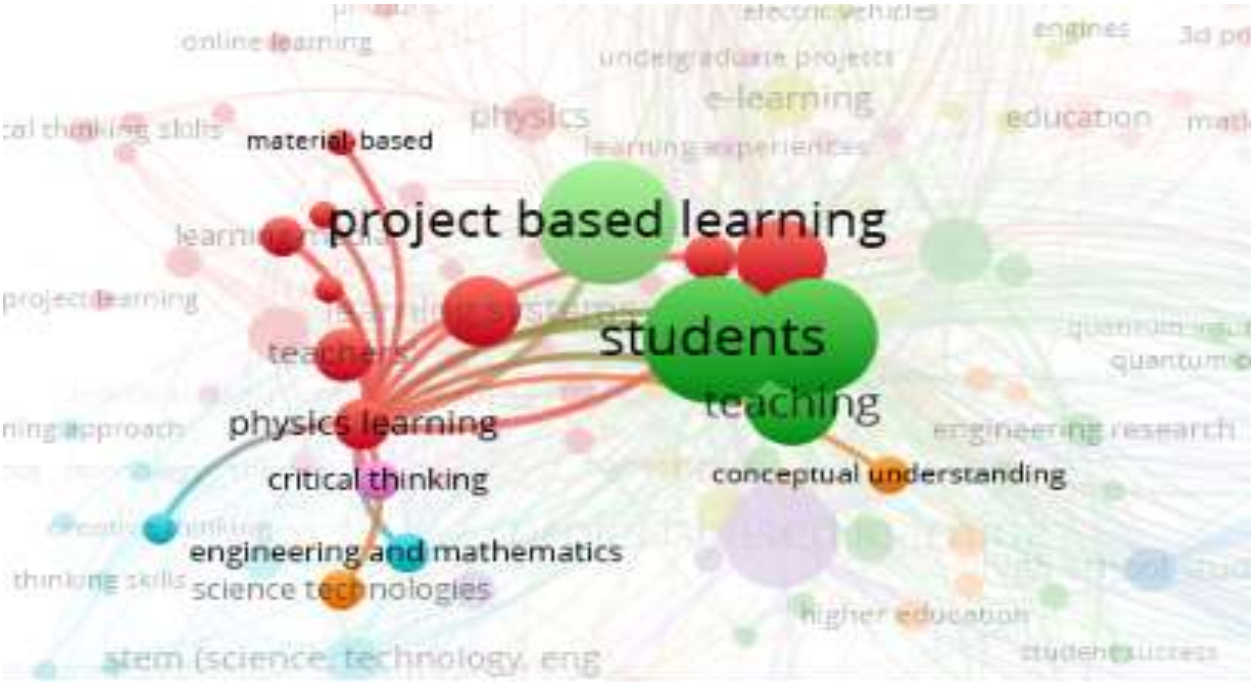


Figure 9. C

Cluster 1 (red), as shown in Figure 9(a), is dominated by the keywords "project-based learning," "physics education," "physics learning," and "critical thinking (skills)," and is connected to technical sub-themes such as "virtual laboratories," "data acquisition," "computer-aided analysis," and "online learning," reflecting the primary research focus on the direct application of PjBL in the context of physics education, the development of critical thinking skills, as well as the use of virtual laboratories and computer-based instrumentation. Cluster 2 (green), shown in Figure 9(b), with central keywords "students," "teaching," "conceptual understanding," and "engineering research," shows a strong emphasis on learner-centered research and conceptual understanding. Cluster 3 (cyan/light blue), dominated by "STEM (science, technology, engineering, and mathematics)," "problem solving skills," "learning models," and "metacognition/metacognitive skills," indicates a close relationship between PjBL and the development of higher-order cognitive skills within the framework of STEM education. Cluster 4 (purple), shown in Figure 9(c), is characterized by "educational technology," "STEM education," "pre-service teachers," and "creative thinking skills," highlighting attention to developing pre-service teachers' competencies as well as integrating educational technology.

In addition to these four main clusters, the overall keyword network visualization (Figure 9) also identified three supporting clusters. The dark blue cluster contains "professional aspects," "programming," "python," and "open source software," representing a more technical sub-theme related to programming skills in engineering-based PjBL. The brown cluster includes "atmospheric chemistry," "nasa programs," "curriculum development," and "undergraduate students," indicating niche research linking physics-based PjBL with atmospheric science and space program topics. Meanwhile, the yellow/olive cluster contains "e-learning," "education," "matlab," "electric vehicles," "engines," and "3d printing," representing a sub-theme of PjBL implementation in more specific engineering contexts, such as electric vehicles and 3D printing. The keywords "project-based learning" and "students" appear as the nodes with the largest size and the highest number of connections in Figure 9, positioning both as central nodes that link nearly all of the other thematic clusters. To further clarify this, Table 1 presents the top ten keywords based on their total link strength values.

Table 1. Top 10 Keyword by Occurrence and Total Link Strength

Rank	Keyword	Occurrences	Total Link Strength
1	Students	57	495
2	Project based learning	55	427
3	Engineering education	47	387
4	Education computing	23	238
5	Project-based learning	41	208
6	Teaching	24	206
7	Curricula	17	158
8	Learning systems	17	143
9	High school students	8	97
10	Professional aspects	6	79

Based on Table 1, the keyword "students" ranks first with 57 occurrences and a total link strength of 495, followed by "project based learning" (55 occurrences, link strength 427) and "engineering education" (47 occurrences, link strength 387). Interestingly, the terms "project based learning" and "project-based learning" appear as two separate entries due to spelling variations that were not automatically merged by VOSviewer this should be noted as a technical limitation of the data processing. The dominance of these two keywords confirms their position as central nodes connecting nearly all thematic clusters, consistent with previous PjBL bibliometric studies (Wahyudi et al., 2024). Furthermore, the appearance of "engineering education," "education computing," and "learning systems" among the top-ranked keywords further confirms that research on PjBL in physics education is developing alongside the integration of educational technology and cross disciplinary approaches, consistent with findings that the terms "students," "teaching," "engineering education," and "curricula" dominate the PjBL science education literature (Nurmasyitah et al., 2025). To further sharpen the findings and recommendations of this study, it is also necessary to examine the most highly cited publications in this field through an SLR approach, in order to identify the strengths and limitations of previous studies as a basis for uncovering future research opportunities in the field of PjBL in physics education.

Table 2. Overview of Most Cited Papers on Project-Based Learning in Physics Education

Author(s)	Citation; SJR	Research Findings and Recommendation
Samsudin, M.A., Jamali, S.M., Zain, A.N.M., & Ale Ebrahim, N. (2020)	55; Q2, SJR 2024: 0.45	A quasi-experimental study involving more than 100 high school students in Malaysia used Bandura's social cognitive theory to compare the effects of STEM-PjBL with conventional teaching methods on students' self-efficacy in learning physics mechanics. STEM-PjBL was shown to enhance learning effectiveness, foster meaningful learning, and influence students' attitudes toward career choices. The study recommends the broader implementation of STEM-PjBL to strengthen students' self-confidence in mechanics.
Al-Kamzari, F., & Alias, N. (2025)	26; Q1, SJR 2025: 0.904	A systematic review of 27 studies on the theoretical foundations, design principles, and implementation of PjBL in secondary school physics. 85% of the studies did not explicitly address the theoretical foundations; only 48%

		implemented all seven core elements of PjBL; and 74% were conducted face-to-face. PjBL has the potential to enhance engagement, curiosity, creativity, and critical thinking. The study recommends integrating blended learning and strengthening the theoretical foundations in the post-COVID-19 pandemic era.
Oyewo, O.A., Ramaila, S., & Mavuru, L. (2022)	22; Q1, SJR 2025: 0.878	A quasi-experimental study using a water treatment-based PjBL activity (utilizing agricultural waste) to enhance STEM students' critical thinking skills. Meaningful challenges connected to real-world issues were shown to capture student interest. The study recommends integrating real-world environmental/social issues into PjBL activities.
Sulaiman, F., Rosales Jr., J.J., & Kyung, L.J. (2023)	17; Q2, SJR 2025: 0.432	A two-group quasi-experimental study involving 88 students in Malaysia and 66 students in Korea learning classical mechanics using a STEM-PBL module, measured using the CLASS instrument. The module was shown to enhance interest, sensemaking, and learning effort compared to the control group. The study recommends cross-cultural implementation to increase student interest in physics.
Montés, N., Aloy, P., Ferrer, T., Romero, P.D., Barquero, S., & Carbonell, A.M. (2022)	14; Q2, SJR 2025: 0.555	A study on the implementation of the EXPLORIA project, which integrates STEAM learning into an engineering mechanics course (a branch of physics) for 24 first-year students in the Industrial Design Engineering program at CEU Cardenal Herrera University, Spain. The learning process was designed as a series of logically connected, progressive challenges and projects, combining various STEAM courses. The results show that this challenge- and project-based approach generated positive feedback from students regarding the relevance and applicability of the material. The study recommends curriculum renewal through innovative pedagogical methods and interdisciplinary content to improve student satisfaction and learning outcomes.

Based on Table 2, the five most highly cited studies show that the implementation of PjBL in physics education consistently produces positive effects across various aspects of learning, ranging from self-efficacy (Samsudin et al., 2020), engagement and critical thinking (Al-Kamzari & Alias, 2025; Oyewo et al., 2022), to student interest and sensemaking (Sulaiman et al., 2023). In addition to its application at the secondary school level, PjBL has also proven relevant for implementation at the higher education level through interdisciplinary approaches such as STEAM (Montés et al., 2022). Nevertheless, these five studies also reveal a number of consistent limitations. (Al-Kamzari & Alias, 2025) found that the majority of PjBL studies in physics have not explicitly addressed their theoretical foundations, which may potentially weaken the conceptual validity of this model's implementation. In addition, most of the studies (Oyewo et al., 2022; Samsudin et al., 2020; Sulaiman et al., 2023) remain focused on geographically limited contexts and samples, meaning that the generalizability of the findings to broader physics education contexts still requires further investigation. These findings reinforce the urgency of more comprehensive bibliometric research, as pursued as the main focus of this study, in order to comprehensively map the patterns and gaps in PjBL research within physics education.

Discussion

The trend analysis covering the 2020–2025 period demonstrates that scholarly attention toward the implementation of Project-Based Learning (PjBL) in physics education has increased significantly, particularly since 2023, reflecting a broader global pattern in which research on active learning approaches continues to expand across educational disciplines. This upward trend is not a phenomenon isolated to physics alone; similar growth has also been documented in global bibliometric mappings of PjBL, which recorded an increase in publications of up to 800% since 2014 (Mota et al., 2025), as well as a significant upward trend in the implementation of PjBL for digital literacy since 2020 (Engrini et al., 2026) and science literacy (Sabrina & Doyan, 2026), reinforcing the notion that PjBL is gradually becoming a mainstream learning approach rather than merely an experimental one. A more in-depth examination of the 156 analyzed documents reveals that physics, as a discipline that is inherently abstract and demands spatial

understanding, benefits substantially from project-based approaches that enable students to apply theoretical concepts through hands-on experimentation and authentic learning experiences (Al-Kamzari & Alias, 2025). This finding is consistent with evidence that PjBL bridges the gap between abstract physics concepts and their practical application, thereby fostering deeper cognitive engagement (Wang et al., 2025), while neurocognitive studies show that sensorimotor-based learning and hands-on activities strengthen the understanding of abstract concepts in STEM learning (Hayes & Kraemer, 2017).

Beyond its specific application in physics, the expansion of PjBL adoption across educational levels from secondary school to higher education has been widely reported, accompanied by persistent challenges such as limited teacher readiness, insufficient methodological training, and infrastructural constraints that continue to shape implementation outcomes(Sánchez-García & Reyes-de-Cózar, 2025). Parallel evidence from PjBL implementation studies across various countries further illustrates how infrastructural disparities between urban and rural areas significantly affect the quality of project implementation, a principle directly relevant to project-based physics laboratory instruction (Ridha Syahdia et al., 2024). The keyword and citation patterns identified in this study also reflect a broader shift in global bibliometric research on PjBL moving from mere demonstrations of feasibility toward more nuanced investigations of student engagement, STEM integration, and cultural/local learning contexts (Yuliani et al., 2025), a shift that is likewise reflected in bibliometric mappings of PjBL within the contexts of digital literacy and science literacy (Engrini et al., 2026; Sabrina & Doyan, 2026). This increasingly mature research development suggests that future studies should prioritize strengthening theoretical foundations as well as more standardized learning outcome measurement frameworks, in order to more comprehensively capture how project-based approaches sustainably influence students' physics learning outcomes (Al-Kamzari & Alias, 2025).

CONCLUSION

This study mapped the effectiveness of Project-Based Learning (PjBL) in physics education (2020-2025) through bibliometric analysis of 156 Scopus-indexed documents combined with an in-depth SLR of the five most cited studies. Findings show that scholarly attention has grown significantly since 2023, led by Indonesia, though cross-country collaboration remains weak and fragmented; keyword mapping reveals PjBL research is closely integrated with STEM, educational technology, and 21st century critical thinking skills; and the SLR confirms PjBL consistently improves self-efficacy, engagement, critical thinking, interest, and conceptual understanding across secondary and higher education levels. Theoretically, these results expose a persistent gap between rapid practical implementation and weak articulation of PjBL's theoretical foundations. Practically, the dominant themes of STEM integration, educational technology, and authentic/local learning contexts offer concrete references for educators and policymakers designing project-based physics curricula, while Indonesia's high output but limited international citation impact signals a need to prioritize research quality alongside quantity. This study is limited by its reliance on a single database (Scopus) and an SLR restricted to only five highly cited documents. Future research should therefore expand to multiple databases (e.g., Web of Science, ERIC), strengthen cross-country collaboration, develop clearer theoretical frameworks for PjBL in physics education, and establish standardized instruments for measuring learning outcomes.

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