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Research Artikel

PROJECT BASED LEARNING IN PHYSICS EDUCATION: A BIBLIOMETRIC REVIEW

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Abstract

Project-Based Learning has been recognized as an effective instructional approach for enhancing conceptual understanding and 21st-century skills in physics education. However, there is a lack of systematic bibliometric studies that map the development, trends, and research gaps in this topic. This study aims to identify research areas that have been extensively explored, as well as those that remain underexplored within PjBL in Physics Education. The method employed is descriptive with bibliometric analysis using data from Scopus, through the stages of identification, screening, eligibility, and inclusion. The analysis was conducted using Publish or Perish and VOSviewer software. From the 48 publications analyzed, it was found that the number of publications declined over the past three years, after peaking in 2021 due to the growing demand for 21st-century competency-based curricula. This decline is suspected to be related to implementation challenges during the COVID-19 pandemic. The distribution of affiliations and countries indicates that there are still institutions and nations not actively involved in this topic. Emerging research focuses, such as links to curriculum, scientific inquiry, and technology, present opportunities for further studies. The findings of this study highlight the need for expanding and deepening PjBL research in Physics Education across various national and institutional contexts.

***Keywords**: Bibliometric analysis; education physics; project-based learning; research trends.*

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INTRODUCTION

Project-based learning (PjBL) is a student-centered learning strategy, that aims to create an interesting and meaningful learning experience. Project-Based Learning (PjBL) is a student-centered instructional model that emphasizes learning through engaging, real-world projects. This approach encourages students to explore and understand concepts by solving complex problems collaboratively, often culminating in the creation of tangible products or presentations. In physics education, PjBL is particularly beneficial because it allows abstract scientific concepts to be contextualized through experiments, engineering tasks, or technological design, making learning more meaningful and applicable to daily life. One of the main characteristics of project-based learning is flexibility, which allows students to be more active in the learning process. PjBL not only increases students' learning motivation (Kiv et al., 2023), but also strengthens students' engagement in challenging activities, from problem investigation to presentation of project results (Miller & Krajcik, 2019). Through this approach, students not only learn theory, but also apply the acquired concepts in real-world situations, which prepares students to overcome challenges in society (Jumini et al., 2021). Therefore, PjBL is a very effective strategy in increasing student motivation and learning skills, which is reflected in the active involvement of students in various stages of the project, especially in physics subjects.

Along with the advancement of education, project-based learning (PjBL) has become a well-researched topic in recent years. One of the notable developments is the integration of PjBL with the STEM (Science, Technology, Engineering, and Mathematics) approach, which is considered highly suitable for secondary schools—particularly in teaching complex, real-world topics such as renewable energy (Azis et al., 2023; Muliyati et al., 2023). The implementation of PjBL-STEM has been proven effective in helping students master 21st-century competencies such as critical thinking, collaboration, and problem-solving (Azis et al., 2023; Berry Devanda et al., 2023) In international contexts, research has shown that STEM-based PjBL fosters scientific literacy, enhances student engagement, and supports deeper conceptual understanding, especially in science and physics education (Roslina et al., 2022).

Despite its benefits, PjBL also presents several challenges in practice, including time-consuming implementation, lack of teacher readiness, limited assessment instruments, and difficulties in managing diverse student abilities during collaborative work (Tain et al., 2023). While PjBL has shown promising outcomes in improving science learning at the secondary level (Pou et al., 2022), few studies have investigated its integration with formative assessment to support individual learning processes (Parno et al., 2022). This highlights the importance of exploring novel strategies and implementation models of PjBL particularly in the physics education context, where practical application and conceptual depth must go hand-in-hand.

There is a growing need to explore more innovative applications of Project-Based Learning (PjBL) in physics education to address existing research gaps and enhance students' learning experiences. This topic has gained increasing attention in recent years, especially regarding the novelty and evolution of PjBL implementation. For instance, Pratiwi and Ikhsan (2024) conducted a bibliometric analysis of PjBL in chemistry education over the past decade, highlighting its potential to offer meaningful learning experiences. Similarly, Dwikoranto et al. (2024) examined the integration of PjBL with problem-based learning (PBL) in physics education over the last eight years. Another study by Anasi and Harjunowibowo (2023) analyzed the trends of PjBL implementation in physics education from 2012 to 2022.

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In the international context, research by Roslina et al. (2022) provided a comprehensive review of science and technology teaching practices, showing how PjBL contributes to inquiry-based and student-centered learning. (Afriana et al., 2016) highlighted the impact of PjBL in promoting STEM literacy among high school students. Ayu et al. (2023) conducted a systematic review of integrated STEM education, noting that PjBL was frequently employed as a core instructional method. In addition, Recent studies also investigated the effectiveness and challenges of implementing PjBL in science and physics classrooms (Gao & Yang, 2023; Purwaningsih et al., 2020; Tain et al., 2023).

These studies demonstrate a growing body of literature on PjBL across various science disciplines; however, there remains a need for a focused bibliometric analysis specifically on PjBL in physics education, to systematically map the existing research landscape and identify emerging themes, trends, and research gaps.Bibliometric analysis is a systematic approach that plays a crucial role in identifying under-researched topics related to Project-Based Learning (PjBL), thereby opening up new opportunities for future research development. By employing statistical techniques and visual mapping, this method enables the evaluation of previous research outputs and the identification of dominant trends within specific fields—such as physics education (Weganofa et al., 2022). In addition to tracking research progress over a defined time span, bibliometric analysis presents findings through visual formats such as graphs, tables, and network diagrams, illustrating topic co-occurrence, author collaboration, and geographic distribution (Sudirman et al., 2023). This approach provides researchers with a comprehensive understanding of the intellectual structure and evolution of a field while highlighting novel contributions and potential research gaps (Kadirhanogullari & Kose, 2023)

In the context of physics education, PjBL is recognized as a strategic learning model to equip students with essential 21st-century skills, including problem-solving, collaboration, and critical thinking. However, a comprehensive global mapping of how PjBL has been implemented and studied in physics education is still lacking. Therefore, this study aims to analyze the research trends and distribution of PjBL in physics education over the past decade (2015–2024). This timeframe was selected to capture both recent developments and long-term patterns in scientific publications. The analysis was conducted using a bibliometric approach based on a systematic literature review, focusing on identifying widely researched themes, underexplored areas, and the global distribution of studies by countries and institutional affiliation. The findings are expected to offer meaningful insights for future research direction and contribute to the development of more effective, relevant, and context-based PjBL strategies in physics education.

METHOD

This study is descriptive research employing a bibliometric analysis approach to examine the development and trends of research on Project-Based Learning (PjBL) in physics education. The method refers to widely adopted bibliometric procedures in prior studies (Merigó & Yang, 2017; van Nunen et al., 2018) and follows five main stages of bibliometric analysis, namely: (1) study planning, (2) data collection, (3) data screening and eligibility, (4) data analysis and visualization, and (5) interpretation of findings. These stages align with internationally recognized bibliometric frameworks (Kadirhanogullari & Kose, 2023; Sudirman et al., 2023), as illustrated in Figure 1.

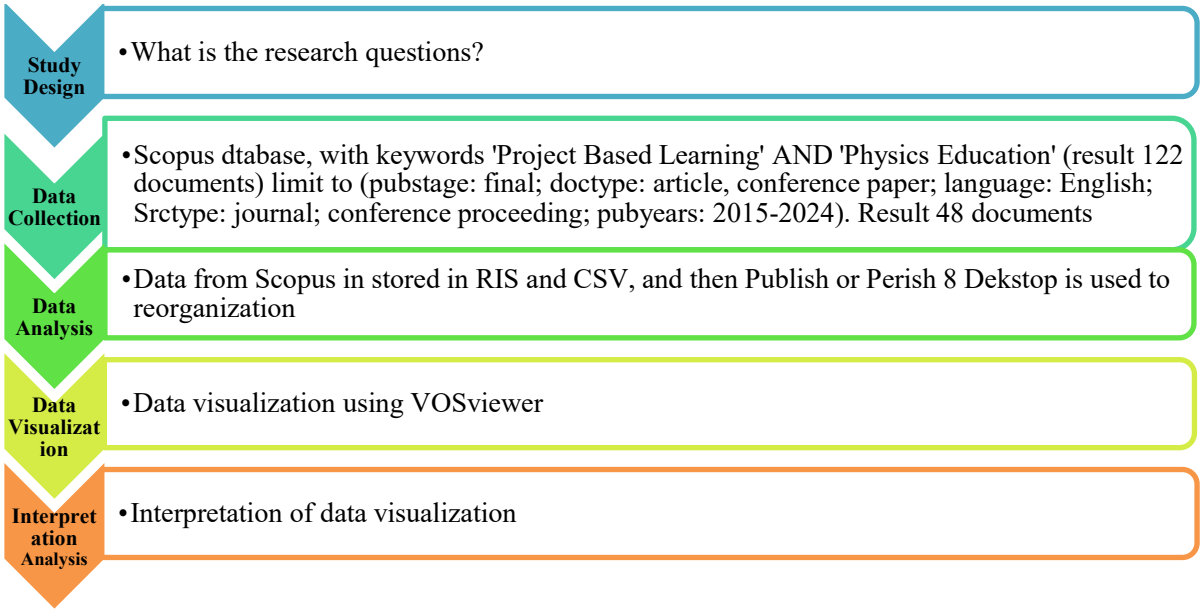

Figure 1. The Steps of Bibliometric Analysis

Figure 1 illustrates the five systematic stages of bibliometric analysis employed in this study. The first stage, Study Design, involved formulating key research questions aimed at guiding the analysis: (1) How has the development of research publications on Project-Based Learning (PjBL) in physics education evolved over the last decade? (2) What is the geographic distribution of PjBL research in physics education across different countries? and (3) What topics related to PjBL in physics education remain underexplored and offer opportunities for future research (novelty)? To answer these questions, a bibliometric approach was conducted using VOSviewer software, enabling the mapping of publication trends, research networks, and thematic clusters within the field.

Data were collected from the Scopus database using advanced search features to ensure the inclusion of high-quality, peer-reviewed literature. The keywords used in the search were: TITLE-ABS-KEY ("Project Based Learning" AND "Physics Education") AND PUBYEAR > 2014 AND PUBYEAR < 2025, which yielded a total of 122 documents. To refine the dataset, a series of inclusion criteria were applied: (1) document types limited to articles, conference papers, reviews, and book chapters; (2) subject area focused on Physics and Astronomy; (3) language of publication was English; and (4) publication years ranged from 2015 to 2024. These criteria were selected to ensure that the data consisted of primary scholarly sources, indexed by reputable international publishers and relevant to the research focus.

After filtering, 48 documents met all the criteria. These documents proceeded to the eligibility stage, where the titles, abstracts, and keywords were manually screened to ensure that each study addressed both Project-Based Learning (PjBL) and Physics Education. Any articles that did not explicitly relate to both elements were excluded. The resulting final dataset of 48 documents was then analyzed using VOSviewer software, which enabled the visualization and mapping of bibliometric networks, including keyword co-occurrence, thematic clusters, and collaboration patterns.

Data Analysis

Data analysis was conducted using two software, namely VOSviewer and Harzing's Publish or Perish (PoP). The data was processed using Publish or Perish software to get the data with the most citations, and VOSviewer software to get research updates on Project

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Based Learning (PjBL) in Physics Education and related co-occurrence keywords (Haryandi et al., 2024; Wicaksono et al., 2025). VOSviewer software allows data to be visualized in the form of network mapping, so that the relationship between keywords related to Project Based Learning (PjBL) in Physics Education can be observed (Zakiyyah et al., 2022). Publish or Perish (PoP) software is used to assist bibliometric analysis due to its ability to efficiently extract and process citation data from various sources, including Scopus (Lukito & Firmansyah, 2024). These tools have been widely adopted in bibliometric studies (Haryandi et al., 2024; Zakiyyah et al., 2022).

The Interpretation Analysis stage was carried out through descriptive analysis of the visualizations and outputs generated by VOSviewer and Publish or Perish (PoP) software. This stage involved interpreting visual data such as publication trend graphs, collaboration network maps, and citation tables to describe the general characteristics of the analyzed literature. Specifically, the analysis focused on identifying patterns of topic concentration, author and institutional collaborations, and research gaps within the field of Project-Based Learning (PjBL) in physics education. Tables were also used to summarize the most productive authors, the most frequently cited journals, and the distribution of publications by country. The goal of this interpretive phase was to present a comprehensive overview of the research landscape, highlight areas that are underexplored, and provide insights that may inform future research directions in PjBL-related physics education.

Descriptive analysis in this study was conducted by interpreting quantitative data displayed through visualizations (such as publication trend graphs, collaboration maps, and keyword diagrams) and tables (e.g. tables of most productive authors, most used journals, and countries of origin of publications). This analysis process aims to thoroughly describe the characteristics of the literature reviewed, including the growth in the number of publications per year, the geographical distribution of research, as well as the most frequently occurring topics and the reasons behind them.

RESULTS AND DISCUSSION

A total of 48 data obtained from Scopus were then analyzed using bibliometric methods. The bibliometric analysis process was carried out with the help of several software. The data obtained are studies that have been published and indexed in Scopus and are relevant to Project Based Learning in physics education. The following are the results of the data analysis which are divided into several sections.

Publication Trends on PjBL in Physics Education

Trends in research publications related to Project Based Learning (PjBL) in Physics Education can be observed in Figure 2.

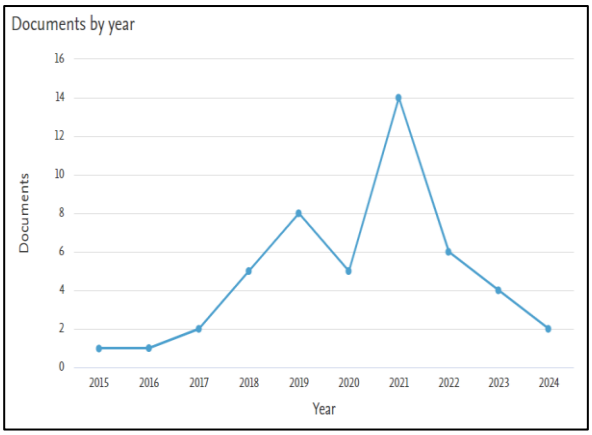

Figure 2. Publication Trends Based on Year

Figure 2 illustrates the annual distribution of publications on Project-Based Learning (PjBL) in physics education from 2015 to 2024. Between 2015 and 2017, the number of publications per year remained relatively low (only 1–2 articles), suggesting that this topic had yet to gain significant scholarly attention. However, a gradual increase began in 2018, followed by a sharp rise in 2021, which marked the highest number of

publications within the examined period. This surge reflects a growing academic interest in PjBL, particularly as a pedagogical response to the demand for innovative and student-centered learning approaches during the COVID-19 pandemic. These findings are consistent with the study by Azis et al. (2023), which reported that the integration of PjBL with STEM approaches, especially in renewable energy topics, gained momentum during the pandemic due to its contextual nature and adaptability for distance learning environments.

International studies also support this trend. For instance, (Fauziah et al., 2023; Saidaturrahmi et al., 2021) emphasized that PjBL supports student engagement and scientific literacy, making it increasingly attractive in uncertain educational conditions. Furthermore Wahyuningsih et al. (2021) noted that the shift to online and hybrid learning during the pandemic accelerated the adoption of flexible pedagogical frameworks like PjBL, which allow for interdisciplinary learning and problem-solving.

Conversely, the decline in publications observed after 2021 may be attributed to several challenges in implementing PjBL under pandemic-related restrictions. Since project-based learning relies heavily on hands-on activities and collaborative engagement, the limitations of remote or hybrid classrooms posed considerable barriers to effective execution (Tain et al., 2023). While PjBL fosters deep learning, it demands substantial teacher preparation, classroom resources, and consistent student interaction—factors that were disrupted during the pandemic.

This pattern indicates that while PjBL remains pedagogically relevant, its implementation is highly sensitive to contextual factors such as learning modality, access to technology, and classroom dynamics. Therefore, future research should consider how PjBL can be adapted for resilient education models that are flexible enough to withstand both traditional and crisis-based learning contexts.

Ranking of 10 Articles with the Most Citations Related to PjBL

In addition to the annual trend analysis, a further evaluation was conducted using the Publish or Perish (PoP) software. This tool was employed to identify and analyze the most influential articles in the data collected based on citation counts. The top ten most-cited articles related to Project-Based Learning (PjBL) in physics education are presented in Table 1, offering insights into the most impactful studies in this field. Furthermore, PoP also provides data on the most recent publications, as shown in Table 2, which highlights the current research directions and focuses related to PjBL.

Table 1. Rangking of 10 Articles with the Most Citations Related to PjBL

No.	Authors	Findings	Cited	Source
1.	Yang, L. (2020)	The implementation of Project-Based Learning (PjBL) in Additive Manufacturing (AM) practice supports students in understanding research methodologies while simultaneously developing practical skills in applied physics	11	The University of Texas at Austin
2.	Retno, N. H. D., Sunarno, W., & Marzuki, A. (2019)	Project based learning method can be used as an alternative for teachers in teaching and learning process to create an active learning environment as well as to improve the students' understanding of physics problems.	9	*Journal of Physics: Conference Series*
3.	Yuliati, L., Munfaridah, N., Ali, M., Rosyidah, F. U. N., & Indrasari, N. (2020)	The operational implementation of PjBl-STEM has a bigger impact compared to PjBl in terms of improving the students' problem-solving skills.	9	*Journal of Physics: Conference Series*

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No.	Authors	Findings	Cited	Source
4.	Purwaningsih, E., Sari, A. M., Yuliati, L., Masjkur, K., Kurniawan, B. R., & Zahiri, M. A. (2020)	The students' problem-solving skills are improved after they experienced the learning prcess using PjBL-STEM model integrated with TPACK.	6	*Journal of Physics: Conference Series*
5.	Montés, N., Aloy, P., Ferrer, T., Romero, P. D., Barquero, S., & Carbonell, A. M. (2022)	The integration of Project-Based Learning (PjBL) with the STEAM approach through the Exploria project in mechanical engineering topics within physics has proven effective in promoting product design and contextual learning	6	*Multidisciplinary Digital Publishing Institute.*
6.	Lukitasari, M., Handhika, J., & Murtafiah, W. (2018)	By using project-based learning that utilizes e-portfolio projects, students' analysis, evaluation, and production skills can be improved in a moderate level.	5	*Journal of Physics: Conference Series*
7.	Mayasari, T., Susilowati, E., & Winarno, N. (2019)	Science content knowledge showed the greatest improvement, followed by engineering, technology, and finally mathematics. Additionally, solar energy projects can help enhance students' STEM achievement and foster meaningful learning experiences.	4	*Journal of Physics: Conference Series*
8.	Solihin, A., Wibowo, F. C., & Astra, I. M. (2021)	In the last several years, PjBL integrated with STEAM has become a trend and has been chosen in the teaching and learning process of physics learning schools.	3	*Journal of Physics: Conference Series*
9.	Ramdhayani, H. G., Purwoko, A. A., & Muntari, M. (2019)	There is an improvement in the science skills of the students using PjBL learning model in the moderate level	3	*Journal of Physics: Conference Series*
10.	Rohman, F., & Fauzan, A. (2019)	The use of Tracker in the practicum activity on PjBL can train students to understand the relation of the abstract physic concept to real life experience by using video analysis. Furthermore, the use of Tracker in practicum activity, can give the students the freedom to create practical projects that will be worked on and effectively used in forming science process skills in practical activities.	3	*Journal of Physics: Conference Series*

Table 1 presents the ten most cited articles discussing the implementation of Project-Based Learning (PjBL) in the context of physics education. Analysis of these articles reveals a tendency for highly impactful studies to integrate PjBL with other pedagogically relevant approaches, such as STEM, TPACK, or STEAM. This trend highlights that cross-approach integration is a key factor in enhancing both the effectiveness of PjBL and the academic competitiveness of the publications.

The most cited article is by Yang (2020), which demonstrates the effectiveness of PjBL in applied physics learning through hands-on experience with Additive Manufacturing (AM). This study attracted significant attention for its integration of PjBL with industrial practices and research methodologies, thereby increasing its relevance to the science and engineering communities. Similarly, studies by Retno et al. (2019) and Yuliati et al. (2020) provide evidence that PjBL fosters active learning environments and improves students'

conceptual understanding, particularly in solving physics problems systematically.

Several articles explicitly highlight the positive impact of integrating PjBL with STEM and TPACK. For example, Purwaningsih et al. (2020) reported that a TPACK-based STEM-PjBL model significantly improved students' problem-solving skills. Likewise, Mayasari et al. (2019) emphasized that implementing PjBL on the topic of solar energy not only enhanced STEM achievements but also provided more meaningful learning experiences.

Furthermore, studies by Montés et al. (2022) and Solihin et al. (2021) underscore the importance of authentic contexts in projects—such as product development and the Exploria approach—which allow students to connect physics theories with real-world applications. This aligns with the literature that states the success of PjBL heavily depends on the relevance of the project to students' lives and its real-world applicability (Ridwan et al., 2022)

Another notable finding is the use of digital technologies in PjBL, such as e-portfolios (Lukitasari et al., 2018) and the Tracker application for video analysis in physics practicum (Rohman & Fauzan, 2019). These studies demonstrate that the integration of digital tools not only enhances student motivation but also strengthens conceptual understanding through data processing and motion visualization crucial components in experiment-based physics learning.

Overall, the most cited articles share common characteristics: the integration of PjBL with modern pedagogical approaches, a focus on developing higher order thinking skills such as problem-solving and scientific skills, and the inclusion of authentic, applicable learning contexts. These findings imply that the success and impact of PjBL research in physics education are determined not only by the learning model itself but also by integrative strategies and contextual relevance.

The search yielded ten of the latest relevant articles that offer significant insights into current developments, challenges, and innovations in the implementation of PjBL. These selected articles are presented in Table 2 and serve as key references for constructing the conceptual framework of this research.

Table 2. Rangking of 10 Latest Articles Related to PjBL

No.	Authors	Findings	Cited	Source
1.	Wen, X., & Korsun, I. (2024).	PjBL are proposed as a learning method in real life cases (penyumbatan kapal) as an effort to improve students' indiciplinary thinking	0	*Physics Education*
2.	Pebriana, I. N., Rahmayanti, A. D., Millen, N. R., Rahman, N. B. A., & Setiaji, B. (2024)	The development of physic e-module that integrating PjBL with STEM in *gerak lurus* material can improve students' creativity and motivation, theoritically.	0	*AIP Conference Proceedings*
3.	Pujante-Martínez, L., Le Clainche, S., Pérez, J. M., & Ferrer, E. (2023).	Project-based learning and game-based learning improve learning motivation and conceptual knowledge of elementary and secondary school students and college students. Research using PjBL for fluid dynamics material.	1	*European Journal of Physics*
4.	Lager, A., Lavonen, J., & Juuti, K. (2023).	Integration of digital tools and project-based learning approaches in teaching physics at the secondary school level can improve students' understanding of physics concepts, especially when studying motion phenomena.	0	*Springer Nature*
5.	Muliyati, D., Prastiawan, F., & Mutoharoh, M. (2023).	Lembar kerja peserta didik STEM-PjBL sebagai media pembelajaran fisika untuk memahami topik energi terbarukan dapat meningkatkan keterampilan abad-21 secara efektif.	0	*Institute of Physics*

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No.	Authors	Findings	Cited	Source
6.	Kiv, A. E., Semerikov, S. O., Striuk, A. M., Osadchyi, V. V., Vakaliuk, T. A., Nechypurenko, P. P., Bondarenko, O. V., Mintii, I. S., & Malchenko, S. L. (2023)	PjBL can improve students' conceptual understanding and problem-solving skills, especially in the context of applied mathematics learning. However, the implementation of PjBL also faces challenges, such as the need for adequate teacher training and adequate resource support.	0	*Journal of Physics: Conference Series*
7.	Montés, N., Aloy, P., Ferrer, T., Romero, P. D., Barquero, S., & Carbonell, A. M. (2022)	This research focuses on how to integrate STEAM learning in PjBL with the EXPLORIA project term to enhance learning in physics courses, and in particular, in the part of the syllabus related to mechanical engineering through various projects, challenges, and milestones that allow students to see the use in product design and development.	6	*Multidisciplinary Digital Publishing Institute.*
8.	Saputri, M., & Syukri, M. (2022).	The implementation of PjBL integrated with STEM gives positive result in improving the critical thinking of students, especially in the materials of impulse and momentum	0	*Journal of Physics: Conference Series*
9.	Ekawati, E. Y., & Prastyo, A. (2022).	Project-based–learning strategy need to give more stimulus to improve TPACK skills especially the pedagogical skills	0	*Journal of Physics: Conference Series*
10.	Dewi, W. S., & Sari, S. Y. (2022).	It is not easy to find evaluations that can be used as project assignments. Physics learning evaluation teaching materials based on project-based learning and portfolio assessment are right for improving students' scientific skills.	0	*Journal of Physics: Conference Series*

Table 2 shows 10 recent articles related to PjBL. In recent years, there has been a considerable amount of research related to PjBL integrated with STEM (Muliyati et al., 2023; Pebriana et al., 2024; Saputri & Syukri, 2022). The development of PjBL is used to improve students' scientific skills, creative thinking skills, TPACK abilities, and interdisciplinary abilitie (Dewi & Sari, 2022; Pebriana et al., 2024; Saputri & Syukri, 2022; Wen & Korsun, 2024) s. PjBL has been applied to several materials such as dynamic fluids, momentum and impulse, straight motion, and kinematics (Lager et al., 2023; Pebriana et al., 2024; Pujante-Martínez et al., 2023; Saputri & Syukri, 2022; Wen & Korsun, 2024). In addition, many PjBL-based media such as modules, worksheets, and portfolios have been developed (Lager et al., 2023; Muliyati et al., 2023; Pebriana et al., 2024; Pujante-Martínez et al., 2023). Some studies also examine the advantages and disadvantages of PjBL (Ekawati & Prastyo, 2022; Kiv et al., 2023; Lager et al., 2023). Technology integration in PjBL does not seem to be widely developed such as the use of Augmented Reality or Virtual Reality. Research novelty can be done through the application of PjBL on other materials, for example on wave or vector materials. In addition, PjBL can be adapted into an improved model considering that PjBL has certain weaknesses.

Distribution of Publications on PjBL in Physics Education

The distribution of publications related to PjBL in Physics Education based on affiliation can be observed in Figure 3 below.

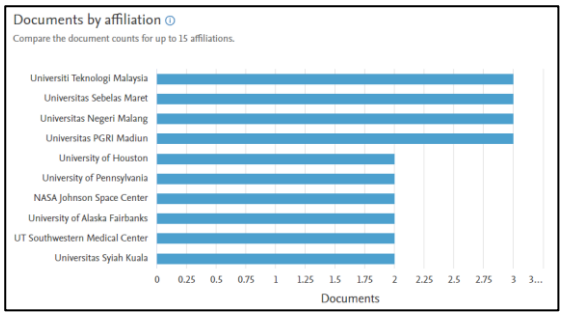

Figure 3. Publication Trends by Affiliation

The distribution of publications on Project-Based Learning (PjBL) in physics education by institutional affiliation is presented in Figure 3. This figure highlights the top 15 institutions that have published the most research in this area. The majority of these affiliations are from Indonesia, including Universitas Sebelas Maret, Universitas Negeri Malang, Universitas PGRI Madiun, and Universitas Syiah Kuala, with a combined total of 11 publications. From Malaysia, Universiti Teknologi Malaysia has contributed three publications. Meanwhile, several institutions from the United States—such as the University of Houston, University of Pennsylvania, NASA Johnson Space Center, University of Alaska Fairbanks, and UT Southwestern Medical Center collectively account for 10 publications. The predominance of Indonesian affiliations suggests that PjBL has become a significant research trend in the country, likely due to its proven effectiveness in enhancing students' skills, particularly in the context of physics education.

Meanwhile, the distribution of publications related to PjBL in Physics Education by country can be observed in Figure 4 below.

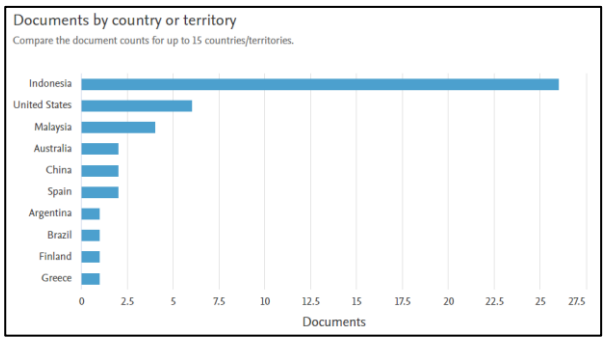

Figure 4. Publication Trends by Country.

Figure 4 illustrates the distribution of publications on Project-Based Learning (PjBL) in physics education by country. The data show that the top three contributing countries are Indonesia with 26 publications, followed by the United States with 6 publications, and Malaysia with 3 publications. The dominance of Indonesian affiliations can be attributed to the growing interest and publication trend surrounding PjBL within the national education context. This aligns with findings that PjBL is effective in enhancing various student competencies, particularly in physics learning that emphasizes scientific processes, collaboration, and real-world project application. Indonesia's leading position reflects the relevance of PjBL to the national curriculum, which emphasizes 21st-century skills, active learning, and project-based approaches. Furthermore, the high number of education-focused universities in Indonesia contributes significantly to the country's research productivity in this area. In contrast, PjBL-related publications in physics education remain relatively scarce in other countries, indicating a geographic gap in research distribution and an imbalance in international contributions. This highlights the potential for fostering international research collaboration and expanding PjBL studies in underrepresented regions within academic literature.

The underexplored topics (novelty) within PjBL in physics education

The novelty of research on PjBL in Physics Education was analyzed using VOSviewer software. The mapping of areas that have been widely published or researched can be observed in Figure 5 below.

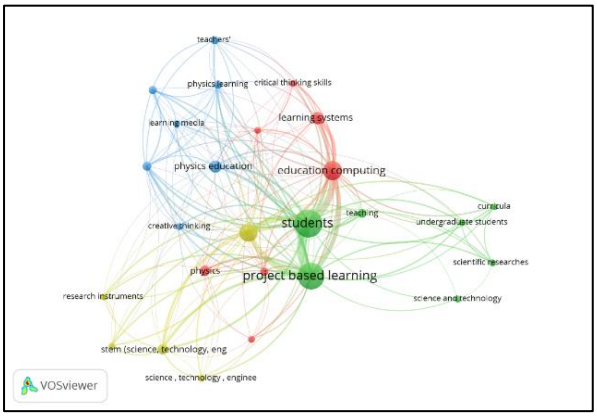

Figure 5. Distribution of PjBL Research Novelties in Physics Education

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Figure 5 shows the mapping of the most keywords related to PjBL from 2015 to 2024. There are 26 keyword items divided into 4 clusters. The clusters can be seen in more detail in Table 3.

Table 3. Keyword Details in Each Cluster

No.	Color Cluster	Number of Items	Keywords
1.	Green	7	*Curricula; Project Based Learning; Science and Technology; Scientific Research; Students; Teaching; Undergraduate Students.*
2.	Red	7	*Critical Thinking; Critical Thingking Skills; Education Computing; High School Students; Learning System; Physics; Science Learning.*
3.	Blue	7	*Creative Thinking; Engineering and Mathematics; Learning Media; Physics Education; Physics Learning; Science Technologies; Teachers*
4.	Yellow	5	*Engineering Education; Problem Solving Skills; Research Instrument; Sciene, Technology, Engineering, and Mathematics; STEM (Sciene, Technology, Engineering, and Mathematics)*

Tabel 3 presents 26 main keywords grouped into four color-coded clusters based on their thematic relationships.

Cluster 1 (Green Cluster): Focus on instructional structure and student engagement.

This cluster comprises keywords such as curricula, project-based learning, science and technology, scientific research, students, teaching, and undergraduate students. It reflects a strong emphasis on curriculum design and project-based instructional practices, with a particular focus on student participation at the higher education level. The keywords “project-based learning” and “students” appear as the most visually dominant nodes in the cluster, indicating that research in this area is heavily centered on pedagogical approaches and student learning outcomes.

Cluster 2 (Red Cluster): Focus on 21st-century skills and science learning

This cluster includes keywords such as critical thinking, critical thinking skills, education computing, high school students, learning system, physics, and science learning. It emphasizes the importance of developing critical thinking skills and integrating educational technology (computational education) into science learning, including physics. The inclusion of “high school students” highlights the application of PjBL at the secondary education level.

Cluster 3 (Blue Cluster): Focus on the role of teachers, media, and technology integration

This cluster consists of keywords such as creative thinking, engineering and mathematics, learning media, physics education, physics learning, science technologies, and teachers. It reflects a focus on instructional media and the involvement of teachers in designing PjBL strategies. Keywords like “learning media” and “teachers” indicate that research in this cluster emphasizes the role of educational resources and educators in implementing PjBL, particularly within engineering and physics contexts.

Cluster 4 (Yellow Cluster): Focus on research development and skill assessment

This cluster includes engineering education, problem-solving skills, research instruments, STEM, science, technology, engineering, and mathematics. It represents studies that concentrate on the development and validation of research instruments, as well as the enhancement of problem-solving skills through STEM-based approaches. The presence of keywords such as “research instruments” and “STEM” indicates a strong interest in structured, multidisciplinary evaluation methods grounded in the PjBL framework.

This visualization illustrates that Project-Based Learning (PjBL) in physics education has been studied from a variety of perspectives, including curriculum design, thinking skills, technology integration, and assessment instrument development. However, the distribution of keywords also reveals several research gaps that present opportunities for future contributions:

Limited integration of advanced technologies

Although keywords such as education computing are present, there is a noticeable absence of terms related to emerging technologies like virtual laboratories, augmented reality, or AI-based learning support. This indicates an opportunity for research that explores innovative, technology-enhanced implementations of PjBL in physics education.

Lack of focus on scientific representation and metacognition

There are no explicit keywords related to representational competence or metacognitive regulation, both of which are crucial in physics learning. This opens a promising research avenue for bridging PjBL with approaches that emphasize representational thinking or reflective learning practices.

Dominance of student-centered contexts, with limited exploration of the teacher's role

Keywords such as "teachers" appear only marginally, despite the essential role educators play in the design, implementation, and assessment of PjBL. There remains substantial room for studies focusing on teacher professional development within the context of PjBL in physics education.

The discussion is carried out by connecting the results with physics learning. This is then adjusted to the research question so that the novelty of the topic in PjBL research is obtained. A deeper analysis was conducted by looking at the mapping of physics learning keywords. The analysis results obtained from VOSviewer are presented in Figure 6.

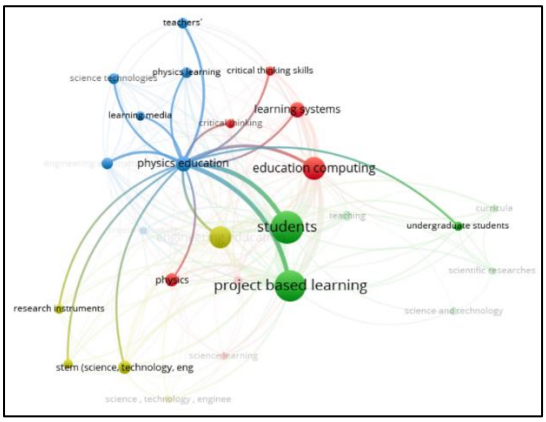

Figure 6. Visualization of Keyword Mapping Related to Physics Education

Figure 6 shows that physics learning is closely linked to Project-Based Learning (PjBL). This is evident from the dominance of keywords such as "project-based learning" and "students" in the green cluster, which reflects studies focusing on both school and university-level learners (Akhiiezer et al., 2023; Akhsani & Eko Subekti, 2021; Azis et al., 2023; Kusuma & Susantini, 2020; Lukitasari et al., 2018; Mayasari et al., 2019; Muhammad et al., 2022; Muliyati et al., 2023). These studies emphasize student engagement in physics through project-based strategies that align with the structure of higher education curricula.

In the red cluster, PjBL is also associated with the development of 21st-century skills, particularly critical thinking and critical thinking skills, as explored by Jumini et al. (2021) and Lukitasari et al. (2018). These skills are considered essential for preparing students for real-world challenges, reinforcing the relevance of PjBL in modern science education.

The yellow cluster highlights PjBL's connection with the STEM (Science, Technology, Engineering, and Mathematics) approach. Research by Azis et al. (2023), Mayasari et al. (2019), and Muliyati et al. (2023) illustrates how PjBL is used to promote interdisciplinary learning and problem-solving within STEM contexts.

However, it is important to note that the keyword mapping in Figure 6 shows a lack of emphasis on technology integration within PjBL studies. Terms such as augmented reality (AR), virtual reality (VR), or interactive digital tools are

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absent, indicating that research exploring the integration of emerging technologies in PjBL is still limited. This gap suggests a promising direction for future studies—namely, enhancing PjBL with up-to-date technologies to support more immersive and effective learning experiences.

Furthermore, the mapping does not visibly represent the development or use of specific instructional media such as worksheets, modules, or learning books. These tools can play a significant role in structuring PjBL activities and guiding student assessment, and their integration presents another area for future exploration and innovation in PjBL-based physics education.

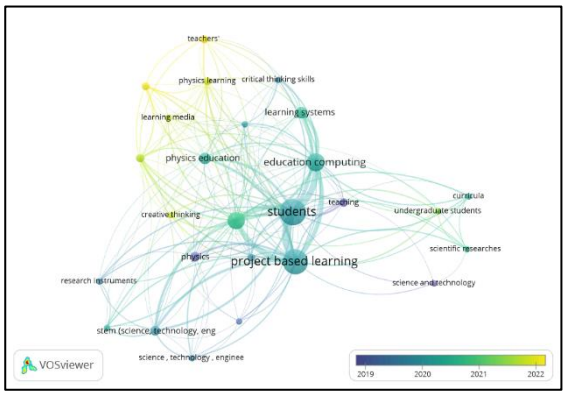

Figure 7. VOSviewer Overlay Visualization Related to PjBL

Furthermore, the mapping from VOSviewer is presented through a visualization of the year of publication, which can be seen in Figure 7. Figure 7 reveals that the keywords of PjBL's newer research are shown in brighter colors (yellow) and older research is shown in darker colors (purple). The keywords that have long been abandoned are teaching, science learning, science technology, and physics. These keywords can be developed again to enrich PjBL studies, such as the application of PjBL to science learning integrated with the latest technology.

CONCLUSION

Research publications related to PjBL have experienced an increase and decrease over the past 10 years. Research increased from 2015–2019, peaked in 2021, and then declined from 2022–2024. PjBL has been studied in various countries such as Brazil and the United States. Unfortunately, the distribution of PjBL research is still not evenly distributed, however, it is centered in Indonesia. Some topics that are still rarely researched and related to PjBL in physics include the application of PjBL using approaches other than STEM such as inquiry or contextual approaches, the application of PjBL in learning media equipped with assessment sheets such as worksheets, modules, or other interactive media, and the application of PjBL using the latest technology such as Augmented Reality (AR) or Virtual Reality (VR). The results of the research are expected to be a study for further research, as well as adding new insights in the field of physics related to PjBL learning that is relevant for use. Nevertheless, several limitations must be acknowledged. This study relied solely on a single database (Scopus), excluded non-English language publications, and involved a relatively small number of samples, which may constrain the comprehensiveness and global representativeness of the identified research trends

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