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Project Based Learning in Science Education Research in Indonesia: A Bibliometric Analysis

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ABSTRACT

Project-based learning (PjBL) is increasingly recognised in science education in Indonesia as a strategy to improve students' higher order thinking skills and real-world problem solving. This article analyses the trends and patterns of PjBL research in Indonesia from 2020 to 2024 using a bibliometric approach. Research data were collected from Google Scholar, Crossref, and OpenAlex databases, then analysed descriptively qualitatively and visualised using VOSviewer. The results of the analysis showed that the majority of studies were experimental (68.36%), focusing on evaluating the effectiveness of PjBL in improving learning outcomes and critical thinking skills, particularly in the context of higher education and digital technology integration. The implementation of PjBL is considered effective in fostering students' creativity, motivation and 21st century competencies. However, there are still implementation challenges that require further study. Based on these findings, it is concluded that PjBL has great potential as a key approach in the Indonesian science curriculum. Therefore, further studies are needed to optimise its effectiveness and overcome the existing obstacles.

1. INTRODUCTION

Research in education plays a vital role in shaping the progress and development of educational practices. Educational research contributes significantly to the advancement of pedagogical knowledge, solving educational problems, and formulating educational policies and development strategies (Rukminingsih et al., 2022) . Several studies have highlighted various factors that influence educational outcomes, including the role of instructional media (Moto, 2019) , the impact of technology integration (Maritsa et al., 2021) , and the influence of religious activities on educational quality (Syukri et al., 2019) , among others.

Project-Based Learning (PjBL) has emerged as a prominent instructional model mandated in the Merdeka Curriculum, both at the elementary and higher education levels. This learning model emphasizes experiential learning, allowing students to engage in real-world problem-solving activities (Wayan et al., 2017) . Previous studies have shown that PjBL can effectively enhance students' higher-

order thinking skills (HOTS) (Andriani et al., 2023; Panjaitan et al., 2020; Yasin et al., 2020) . Consequently, research on PjBL has gained momentum, especially in higher education settings, involving student-led investigations (bachelor's theses, master's theses, and dissertations) and faculty-led investigations.

The growing trend in project-based science education research also emphasizes the need for students to develop the ability to select and design products as part of their problem-solving process. In addition to understanding the underlying issues, it is important to examine how these research trends impact students' abilities in science education. Bibliometric analysis has become a widely used method for identifying and analyzing research trends in this domain. When presented through visualization, bibliometric data can offer clearer insights into key research patterns (Nandiyanto et al., 2020) .

Several previous studies have used bibliometric analysis in the context of science education. For example, Dewi (2021) analyzed trends in STEM-based physics education, while other researchers examined topics such as the Science, Technology, and Society (STS) approach (Okta, 2022) and problem solving in physics teaching (Putri, 2021) . However, to date, there has been no study that specifically analyzes the trend of project-based science education research in Indonesia using bibliometric techniques. This gap shows that there has been no comprehensive study that maps how project-based learning has been researched and developed in the context of science education in Indonesia, so research is needed that fills this gap by conducting an in-depth bibliometric analysis focused on project-based learning. Thus, this study aims to fill this gap by providing a comprehensive overview of the trends, patterns, and developments in project-based learning research in the field of science education in Indonesia using bibliometric methods.

2. METHODS

This study uses a descriptive qualitative research design. Descriptive qualitative research is conducted to gather information about the current status of a phenomenon, describing it as it occurs naturally at the time of the study. A bibliometric approach is used to analyze research trends in project-based science education in Indonesia. The descriptive method was chosen to provide a detailed and systematic picture of the development and direction of research in this field.

In conducting this research, data were not collected from the entire population, but from a sample that was considered representative. This approach was based on practical considerations, such as limited time, resources, and accessibility. Therefore, the findings obtained from the sample can be generalized to a wider population. In line with the scope of the research, the population consisted of all research related to project-based science learning conducted in Indonesia. The sample includes development-oriented research studies published and indexed in databases such as Google Scholar, Crossref, and OpenAlex. The stages of the research process are illustrated in Figure 1.

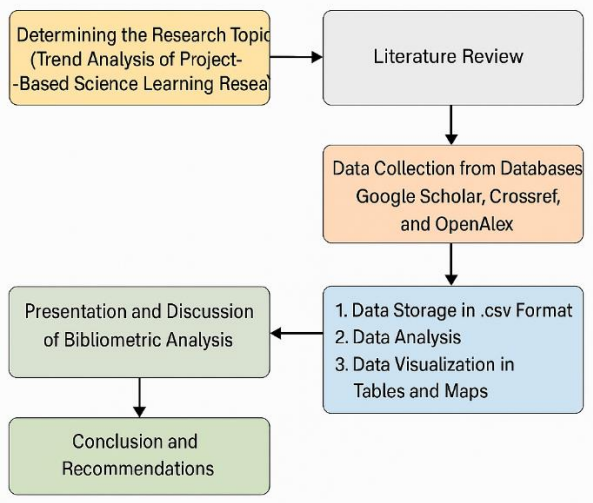

Figure 1. Research Procedure Diagram

The main research instrument used in this study is document analysis. According to Arikunto (2010) , the documentation method involves collecting data from various sources such as notes, transcripts, books, newspapers, magazines, inscriptions, meeting minutes, and agendas. In this study, the documentation process involves collecting a database of research publications on project-based science education from 2020 to 2024 using Google Scholar and OpenAlex that focus on Project-Based science learning, development-oriented research *or* relevant empirical research, published in journals or proceedings indexed in Google Scholar, Crossref, and OpenAlex, and written in Indonesian or English. After the initial search, a screening process of the title, abstract, and contents of the article was carried out to ensure compliance with the inclusion criteria. Articles that met the criteria were then further analyzed.

The data analysis technique applied is qualitative descriptive analysis. According to Sugiyono (2013) , qualitative data analysis can be done through domain analysis, taxonomy analysis, component analysis, and cultural analysis. In this study, the process follows three main stages: data reduction, data display, and conclusion drawing. Data reduction involves filtering the collected data according to the research topic—namely, trends in project-based science education—followed by organizing similar data to ensure accuracy. Data display presents information in tabular form, including columns related to research methods and types of educational products developed. The data is then visualized using VOSviewer software to map the bibliometric network. Conclusion drawing involves synthesizing the findings into a descriptive summary and providing recommendations based on the observed research trends.

3. RESULT AND DISCUSSION

Data collection was conducted using the Publish or Perish application with the following keywords: project-based learning, PjBL, science, physics, chemistry, and biology. Data were taken from the Google Scholar and OpenAlex databases. After being collected, articles were categorized by field of study and further analyzed based on the research methods used to provide deeper insight into project-based learning (PjBL) research trends.

A total of 392 articles published between 2020 and 2024 were identified using the selected keywords. The study was then categorized based on the type of research—experimental, developmental,

and analytical—to identify the dominant research trends in the last five years. The results of this classification are presented in **Table** 1.

Table 1. Distribution of PjBL Research Based on Research Design

No	Research Methods / Design	Number of Articles
1	Experimental	268
2	Development	64
3	Analytical	60
All over		392

Based on Table 1, research related to PjBL is categorized into three main groups: experimental, developmental, and analytical studies. Experimental methods are the most dominant, with 268 studies (68.36%) conducted between 2020 and 2024. Experimental studies are mainly used to examine the effectiveness of PjBL on various educational variables such as student learning outcomes, critical thinking skills, collaboration abilities, and learning motivation.

Experimental research plays an important role by providing empirical evidence on how PjBL improves educational outcomes. For example, Sari (2020) reported that project-based learning significantly improved students' critical thinking and problem-solving skills compared to traditional approaches. This study used an experimental design by comparing a PjBL treatment group with a control group using conventional learning strategies. In addition, many experimental studies have explored the integration of Digital Technologies in PjBL, showing increased student engagement and achievement (Fitriani et al., 2021) . Other experimental studies have focused on the implementation of PjBL across science, mathematics, and language subjects to assess its effectiveness in different educational contexts.

The Developmental Research in PjBL has also played a significant role in improving the quality of science education. A total of 64 studies (16.33%) focused on the development of PjBL-based instructional modules or tools. These studies aimed to design, evaluate, and refine educational products such as learning modules, digital applications, and assessment instruments. One important finding is that technology-based PjBL modules have helped teachers in implementing PjBL, especially in distance learning settings. For example, Santoso (2021) demonstrated the practical efficiency of such tools in adapting to the evolving demands of education. These products often undergo limited trials before widespread implementation to ensure effectiveness and relevance. Many studies use the ADDIE MODEL to develop instructional modules systematically, offering clear guidance for teachers. This type of research not only supports the implementation of PjBL in the classroom but also aligns with the evolving curricular demands and rapid advancements in educational technology—thus forming the basis for innovative and responsive teaching practices.

Finally, analytical studies account for 60 articles (15.31%) and often use qualitative or descriptive quantitative approaches to explore the implementation, challenges, and long-term impacts of PjBL. These studies may involve literature reviews, teacher or student surveys, and in-depth analysis of trends, perceptions, and barriers to implementing PjBL. A study by Wijaya et al. (2022) , for example, identified time constraints , limited resources , and lack of professional development as key barriers to effective PjBL implementation. These findings highlight the practical challenges faced by educators, particularly in Indonesian secondary schools, and emphasize the need for targeted support in PjBL integration.

Further research, such as that conducted by Kurniawan (2023) , emphasizes that while project-based learning (PjBL) can significantly improve students' collaboration skills, its success is highly dependent on the availability of adequate tools and supporting learning facilities. Insights drawn from analytical studies such as these are crucial, as they highlight the influence of educational policies, teacher

perceptions, and institutional readiness on PjBL implementation. By identifying these challenges, the study not only describes the current state but also contributes valuable recommendations for improving PjBL implementation in the future. This understanding serves as a foundation for developing a more effective and responsive education system.

Another study conducted by (Konu Kadirhanogullari, M. & Ozay Kose, E., 2024) showed that studies on project-based learning in science education have grown significantly from 1994 to 2023, peaking in 2019. Bibliometric analysis identified key keywords such as "project-based learning", "STEM", "engineering", and "science education", and highlighted the most productive authors and important sources in this field. The results of this study provide an overview of current research trends and help researchers and educators understand the development and future directions of project-based learning in science education. In addition, this study emphasizes the importance of expanding research with new keywords and approaches and strengthening interdisciplinary approaches in the development of project-based learning.

In addition, research (Lin, S. et al., 2023) shows that the development of research on Project-Based Learning (PBL) inside and outside mainland China shows a rapid growth trend and significant differences in focus and depth of research. Research outside China tends to be more mature and broad in disciplines, while in China it is still in the developing stage and is more limited to teaching reform at the elementary to higher education levels. However, international collaboration in the field of PBL is still relatively limited, so there is a need to increase cross-country cooperation and academic exchanges to strengthen PBL research and implementation globally. Suggestions include more in-depth research on trend issues, development of international projects, and the establishment of international collaboration networks to encourage its further growth and development.

Research (Hasni, A. et al., 2016) shows that various studies on project-based learning (PBSTL) at the K-12 level generally agree that this approach is an effective way to improve understanding of science and technology concepts, as well as promote 21st-century skills such as collaboration, creativity, and problem solving. Many studies also indicate that PBSTL can increase students' motivation and interest in STEM. This study also shows that PBSTL is believed to be an innovative approach that can enrich the S&T learning process in elementary and secondary schools. However, research in this area still needs to develop a more rigorous methodology and use a stronger conceptual framework so that the results are more reliable and generally applicable. In addition, more in-depth research is needed on the influence of PBSTL on students' interest and motivation and the development of a theoretical framework that supports the implementation and evaluation of this approach consistently in various school contexts.

In addition to classification based on research design, the collected data were also categorized based on research focus or dependent variables . A total of 17 thematic categories were identified from the data set. The distribution of these research focuses is presented in **Table** 2 .

Table 2. PjBL Research Analysis Based on Research Focus

No	Research Focus	Number of Studies
1	Creativity	100
2	Critical thinking	36
3	Motivation to learn	10
4	Learning Outcomes	110
5	Scientific Literacy	17
6	Active Learning	5
7	Soft Skill	2
8	Conceptual Understanding	22

No	Research Focus	Number of Studies
9	Higher Order Thinking Skills	9
10	21st Century Skills	42
11	Communication Skills	1
12	Writing Skills	1
13	Learning Independence	2
14	Solution to problem	4
15	Collaboration	3
16	Project Implementation	1
17	Scientific Process Skills	27
All over		392

Project-based learning (PBL) has become an increasingly popular instructional model and has been widely studied in a variety of educational settings. Table 2 presents trends in PBL research over the past five years, revealing a variety of research focuses, including learning outcomes, creativity, 21st century skills, critical thinking, scientific process skills, conceptual understanding, scientific literacy, learning motivation, higher order thinking skills (HOTS), collaboration, writing skills, communication skills, student engagement, self-directed learning, problem solving, soft skills, and project implementation.

Learning outcomes emerged as the most frequently studied focus area, reflecting the primary goal of PjBL—to improve student achievement. Numerous studies have reported that PjBL improves material comprehension, student engagement, and overall academic performance. The emphasis on both cognitive and affective learning outcomes serves as an important indicator of successful instructional interventions (Hanif et al., 2021) .

Creativity is the second most prominent research focus. PjBL provides an environment that fosters creative thinking, problem solving, and the production of innovative solutions. In the 21st century, creative abilities have become important not only in education but also in the workforce (Barak, 2012) . In addition, PjBL has been shown to be effective in cultivating 21st Century Skills , including creativity, critical thinking, collaboration, and communication (Bell, 2010) . This is supported by the presence of 42 studies that focus specifically on 21st Century competencies.

The number of studies focused on Critical Thinking is also quite large, with 36 studies discussing this aspect. Research has shown that PjBL enables students to develop critical thinking skills through structured exposure to complex problems that require sound analysis, evaluation, and decision-making (Gültekin, 2016) . In science education, PjBL is particularly effective because it engages students in experimental activities, data collection, and hypothesis testing, thereby deepening their understanding of the scientific process and its application in real-world contexts (Chin & Chia, 2006) .

While scientific literacy has received less attention than learning outcomes or creativity, it remains a significant area of interest. PjBL enhances students' ability to understand and apply scientific and technological knowledge to everyday life, making science education more relevant and meaningful (Holbrook & Rannikmae, 2009) . Although fewer studies have examined learning motivation , existing research suggests that PjBL can enhance students' motivation by enabling them to engage in personally meaningful projects (Bender, 2012) . Further study is needed to better understand the role of PjBL in motivating learners across educational settings.

Higher-order thinking skills (HOTS) —including analysis, evaluation, and synthesis—are critical in today's educational context. PjBL challenges students to engage in these complex cognitive processes

when tackling extended, open-ended tasks (Zohar & Dori, 2003) . However, more research is needed to explore the specific impact of PjBL on HOTS. Collaboration , a core element of PjBL, remains underexplored. Group work is an integral part of the PjBL model, requiring students to share ideas and navigate team dynamics. Understanding the factors that influence effective collaboration in PjBL environments would contribute significantly to theory and practice (Krajcik & Blumenfeld, 2006) .

Research on writing and communication skills in PjBL is scarce. However, these competencies are critical, as students are often required to produce written reports and present project results (Larmer & Mergendoller, 2015) . Investigating how PjBL can support the development of these skills would offer valuable insights. Areas such as student engagement , self-directed learning , and problem solving have received limited research attention despite their strong relevance to the goals of PjBL. These dimensions are fundamental to the development of learner autonomy and the ability to address real-world challenges. Thus, more focused studies are essential to fully understand the potential of PjBL in nurturing these critical skills.

The relationship between various keywords in project-based learning (PjBL) research is illustrated in Figure 2. This figure was generated using VOSviewer software by inputting a CSV dataset extracted through the Publish or Perish application.

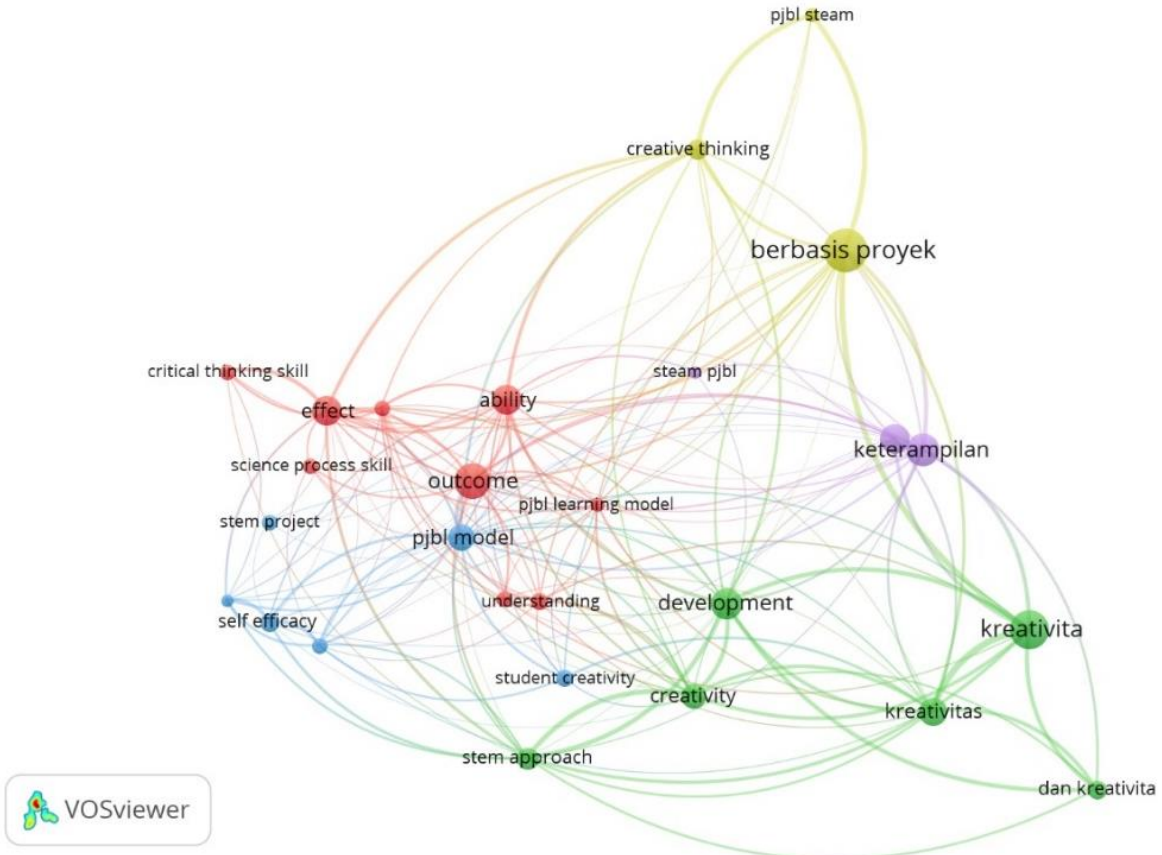

Figure 2. Visualization of Bibliometric Network of Keywords Generated Using VOSviewer

Based on Figure 2, several key interconnected concepts emerge within the scope of Project-Based Learning (PjBL) research, such as STEAM, creativity, and critical thinking skills. These connections provide insights into how the PjBL model contributes to various educational outcomes. In particular, a strong relationship emerges between the PjBL model and student learning outcomes, emphasizing the model's capacity not only to actively engage students but also to enhance important competencies such as critical thinking and creativity.

Capraro et al. (2022) showed that PjBL can significantly increase student engagement while fostering critical thinking, creativity, and problem solving—essential skills for 21st-century learners. Furthermore, integrating the STEAM (Science, Technology, Engineering, Arts, and Mathematics) framework with PjBL appears to strongly support the development of creativity. Through STEAM-based PjBL, students are encouraged to think interdisciplinary and design innovative solutions to real-world problems. Herro and Quigley (2021) found that the application of STEAM in project-based learning promotes creativity through interdisciplinary learning and creative problem-solving processes.

A strong relationship was also evident between critical thinking skills, science process skills, and learning outcomes in the context of PjBL. This model promotes the development of students' analytical and scientific reasoning skills, which are essential for understanding complex scientific concepts. Belland (2020) reported that PjBL integrated with STEM/STEAM significantly improved students' critical thinking skills, especially when aligned with in-depth inquiry-based tasks. In addition (Miller & Krajcik, 2019) found that integrating PjBL with the development of science process skills contributed to a deeper understanding of scientific concepts and improved students' practical science competencies.

Overall, while some focus areas receive more research attention, less explored domains in PjBL studies still have great potential for educational advancement. Project-Based Learning has demonstrated its role not only in improving academic achievement but also in nurturing key competencies needed for 21st century education.

4. CONCLUSION

The findings of this study on Project-Based Science Education Research Trends in Indonesia highlight the significant role of Project-Based Learning (PjBL) in improving the quality of science teaching in the Indonesian context. This study successfully maps research trends related to PjBL implementation from 2020 to 2024, emphasizing key variables such as creativity, learning outcomes, 21st-century skills, critical thinking, and higher-order thinking skills (HOTS).

One of the important findings is that PjBL is mostly applied in experimental research designs, accounting for about 68.36% of the total studies analyzed. These experimental studies mainly focus on examining the effectiveness of PjBL in fostering cognitive and affective learning outcomes, especially in developing students' critical thinking and problem-solving abilities.

In addition, the results of the study showed that PjBL was consistently effective in promoting student creativity, cultivating 21st century skills, and improving scientific literacy. This underscores the potential of PjBL not only as a pedagogical approach to improve academic performance but also as a transformative model for equipping students with competencies essential to the demands of modern science education.

Further research is recommended to explore the implementation of PjBL at more diverse educational levels, including secondary and tertiary education, and in various science subjects specifically. In-depth qualitative studies are also needed to understand the barriers and adaptation strategies of PjBL in various school contexts in Indonesia. In addition, longitudinal research that explores the long-term impact of PjBL on the development of students' 21st century skills and scientific attitudes is needed to strengthen the evidence of the effectiveness of this method.

These findings indicate the need for more systematic integration of PjBL into the science education curriculum in Indonesia. Policy makers and curriculum developers should consider incorporating PjBL as one of the main approaches in science learning to improve students' creativity, critical thinking skills, and scientific literacy. In addition, teacher training and professional development need to be focused on improving the ability to design and manage effective project-based learning, so that teachers can optimally implement PjBL in the classroom.

Further research on Project-Based Learning (PjBL) in science is needed to understand its long-term impact on knowledge retention, critical thinking skills, and student interest, especially in the increasingly relevant context of blended and distance learning. It is also important to examine how technology can enhance the effectiveness of PjBL and its contribution to 21st century skills such as

collaboration and problem-solving. Comparative studies of PjBL with other approaches and the development of authentic assessment strategies are also recommended. The implications of this study for the curriculum are the integration of PjBL as a core approach, a more flexible curriculum, an emphasis on science process skills, realistic time allocation, and the availability of supporting resources. Meanwhile, for teacher development, the implications include intensive training on PjBL methodology, a focus on the role of the facilitator, the development of authentic assessment skills, the formation of a community of practice, and ongoing support and training in technology integration.

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