

Scientific Mapping Research on the Integration of the PjBL Model and Sustainable Development: A Bibliometric Analysis

Cindy Fatika Jeansky Tasilipet¹, Asrizal^{2*}, Harman Amir³, Fauziah Ulmi⁴, Azifa Feziyasti⁵
^{1,2,3,4,5} Department of Physics, Universitas Negeri Padang, Padang, Indonesia.

Article Info

Article history:

Received July 4, 2026

Revised July 18, 2026

Accepted July 27, 2026

Keywords:

Bibliometric Analysis
Education for Sustainable
Development
Project-Based Learning
VOSviewer

ABSTRACT

The integration of Project-Based Learning (PjBL) and Education for Sustainable Development (ESD) has become an increasingly studied learning approach because it supports the development of 21st-century competencies and sustainability. This study aims to analyze trends in publications, subject area, country distribution, network visualization, overlay visualization, and density visualization. Research themes relate to the integration between Pjbl and END during the 2015-2025 period. The method used was bibliometric analysis utilizing articles indexed in the Scopus database. The analysis was conducted using Bibliometric and VOSviewer through the mapping of publication trends, author collaborations, keyword co-occurrence, and the evolution of research themes. The results show that publications on the integration of PjBL and ESD have increased significantly, with a focus on active learning, sustainability competencies, critical thinking skills, and the achievement of the Sustainable Development Goals (SDGs). This study provides an overview of the direction of PjBL and ESD research and serves as a reference for researchers and education practitioners in developing learning innovations oriented toward sustainable development.



This work is licensed under a [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/).

*Correspondence:

Asrizal, Department of Physics, Universitas Negeri Padang, Padang, Indonesia.

• email : asrizal@fmipa.unp.ac.id

INTRODUCTION

The advancement of globalization, the fourth industrial revolusi (industry 4.0), and Digital transformation has brought about fundamental changes in reshaped the demands placed on education. Education is no longer solely focused on the acquisition of knowledge but is also expected to equip learners with twenty-first-century skills, including critical thinking, creativity, communication, and collaboration (4C) (Asrizal et al., 2026; Feziyasti & Ashel, 2025; Miller et al., 2025). These skills are essential for enabling learners to address the challenges of modern life, technological advancements, and the increasingly complex world of work. Consequently, the development of 21st-century competencies has become one of the primary priorities to contribute to the improvement of educational quality across countries (Herlinawati et al., 2024; Hilmiatussadiah et al., 2024; Nazifah & Asrizal, 2022). Therefore,

learning processes should be designed to be active and learner-centered in order to foster the optimal development of these competencies.

Education for sustainable development (ESD) has become a global agenda that recognizes education as one of the key instruments for achieving a sustainable society. The concept of ESD encourages learners to develop the knowledge, skills, values, and attitudes necessary to promote environmental, social, and economic sustainability (Fernando & Tajan, 2024; Huang et al., 2024). ESD is a fundamental component in achieving the Sustainable Development Goals (SDGs), particularly Goal 4, which aims to ensure inclusive, equitable, and quality education while promoting lifelong learning opportunities for all (Holst et al., 2024). The integration of sustainability principles into the learning process is expected to enhance learners' awareness of global challenges while encouraging them to actively participate in developing sustainable solutions to these issues (Cordova, 2024). Therefore, the implementation of ESD has become one of the key strategies for advancing the transformation of twenty-first-century education (Faizah et al., 2026).

Physics Education serves as a strategic instrument for promoting sustainable development, as many physics concepts are closely related to energy, the environment, climate change, and technological advancement. Physics learning aims not only to enhance students' conceptual understanding but also to develop their ability to analyze and solve real-world problems through scientific reasoning (Nurdiansyah et al., 2026). The integration of Sustainable Development principles into physics education enables learners to understand the relationship between scientific concepts and real-world contexts. This approach also fosters the development of critical thinking, problem-solving skills, and environmental awareness (Novita et al., 2025). Therefore, physics education makes a significant contribution to the implementation of ESD.

Project-Based Learning (PjBL) is a learner-centered instructional model that engages students in completing projects based on authentic, real-world problems. This model effectively promotes the development of critical thinking, creativity, communication, and collaboration, which are regarded as essential competencies for twenty-first-century learning (Adekantari et al., 2020). The implementation of PjBL in physics education provides learners with opportunities to connect scientific concepts to real-world phenomena in their surrounding environment. Numerous studies have demonstrated that PjBL can enhance problem-solving skills while fostering awareness of sustainability-related issues. Therefore, the integration of PjBL with ESD has become an increasingly prominent focus in educational research (Nurdiansyah et al., 2026).

Research on the integration of PjBL and ESD has grown considerably over the past several years. Numerous studies have examined the effectiveness of PjBL in enhancing learners' competencies while simultaneously incorporating the principles of ESD into the teaching and learning process. Several bibliometric studies have also mapped the development of research publications on PjBL and ESD as separate fields of study. These studies have reported a steady increase in publication output, research collaboration, and the evolution of research themes over time. This trend indicates that the integration of Project-PjBL and ESD has become an increasingly significant and emerging topic in the field of education (Asrizal et al., 2025; Zulaika et al., 2022).

However, bibliometric research on the integration of PjBL and ESD remains limited. Most previous studies have focused on mapping the development of either PjBL and ESD as separate research domains, thus providing only a limited understanding of the integration between these two concepts (Rahmawati et al., 2025). Information regarding publication trends, collaboration networks, emerging research themes and future research directions

opportunities has not yet been comprehensively examined. As a result, the overall direction and development of research on the integration of PjBL and ESD remain insufficiently understood. Therefore, a bibliometric study that systematically maps the integration of these two concepts is still highly needed (Fatmawati et al., 2026).

The increasing number of publications on the integration of PjBL and ESD indicates that this topic has attracted growing attention in educational research. However, research trends, the direction of scholarly inquiry, and both emerging and declining research themes have not yet been comprehensively mapped, making it difficult for researchers to understand the evolution of this field. Furthermore, identifying research gaps remains essential to determine promising opportunities for future studies more accurately. The complex relationships among authors, institutions, countries, and keyword connections have also not been systematically analyzed, leaving the knowledge structure and patterns of scientific collaboration in this field insufficiently understood. Therefore, a bibliometric analysis is essential to systematically investigate publication trends, intellectual structures, collaboration networks, and the evolving body of scientific literature, thereby offering a comprehensive understanding of the evolution and future research directions in the integration of PjBL and Sustainable Development.

Bibliometric analysis is a quantitative method used to evaluate the development of a scientific field based on scholarly publication data. This method enables the identification of publication productivity, influential authors, institutions, countries, collaboration patterns, citation networks, and the evolution of research themes (Öztürk et al., 2024; Syafri, 2026). Software such as VOSviewer enables the systematic visualization of relationships among keywords, author collaborations, and research trends. These visualizations provide a more comprehensive understanding of the development of a research field while facilitating the identification of emerging topics and future research opportunities (Du et al., 2024). Therefore, bibliometric analysis offers a systematic and reliable approach to investigating and mapping the evolution of research on the integration of PjBL and Sustainable Development (Donthu et al., 2021; Hadiastriani & Djarot, 2024).

Research on the integration of PjBL and ESD requires a comprehensive scientific mapping to provide a clear overview of the development of this research field. Information regarding publication trends, scientific collaboration, research themes, and the direction of future research still needs to be systematically analyzed using a bibliometric approach. Such mapping is expected to identify existing research gaps while highlighting potential opportunities for future research and development (Fatmawati et al., 2026). This study employs a bibliometric analysis of publications published between 2015 and 2025, using VOSviewer software to visualize the development of research in this field. The findings are expected to serve as a valuable reference for researchers, educators, and curriculum developers in designing and improving physics education that supports ESD.

METHODS

This study employs bibliometric analysis using a descriptive quantitative approach to map the evolving body of research on the integration of Project-Based Learning PjBL and ESD was chosen because it is a systematic method for exploring and analyzing a body of scientific publications, enabling researchers to identify trends in a particular field, emerging themes, and opportunities for future research (Donthu et al., 2021). The research data were obtained from the Scopus database covering the years 2015–2025, using English-language journal articles relevant to the research topic. The article identification and selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analyses) guidelines to ensure that the analyzed articles met the inclusion and exclusion criteria. The

literature search was conducted by combining the keywords “Project-Based Learning” AND “Education for Sustainable Development” to yield more specific results and cover various terms related to the topic (Page, 2021).

The article metadata were subsequently exported in CSV format and analyzed using VOSviewer to visualize keyword co-occurrence networks and identify conceptual relationships among research topics (Kirby, 2023). Furthermore, bibliometric analysis was conducted to evaluate the publication productivity of authors, journals, institutions, and countries, as well as to explore the changing patterns of research topics over time. This analysis also enabled the identification of influential publications, collaboration patterns among researchers, and the intellectual structure of the research field. The findings were then interpreted using both performance analysis and science mapping approaches to obtain a systematic understanding of publication performance, knowledge structures, and research networks. Consequently, these approaches provided a comprehensive overview of publication trends, collaboration patterns, thematic development, and future research directions concerning the integration of Project-Based Learning (PjBL) with Education for Sustainable Development (ESD) (Mondal, 2026).

The research procedure was conducted in a phased and systematic manner to ensure that the analysis process was focused and aligned with the research objectives. The research phases were based on the bibliometric analysis framework proposed by(Irawan et al., 2024), which includes topic research and keyword searches, collection of article metadata from scientific databases, data selection, bibliometric analysis, visualization of results, and interpretation of research findings. Each stage is conducted to obtain data that is valid, relevant, and aligned with the focus of the study, ensuring that only articles meeting scientific criteria are included in the analysis. The findings are presented in the form of tables and graphs, and network visualizations to provide a clear picture of publication trends, collaborations, and the progression of research themes associated with the integration of Project-Based Learning (PjBL) and Education for Sustainable Development (ESD).

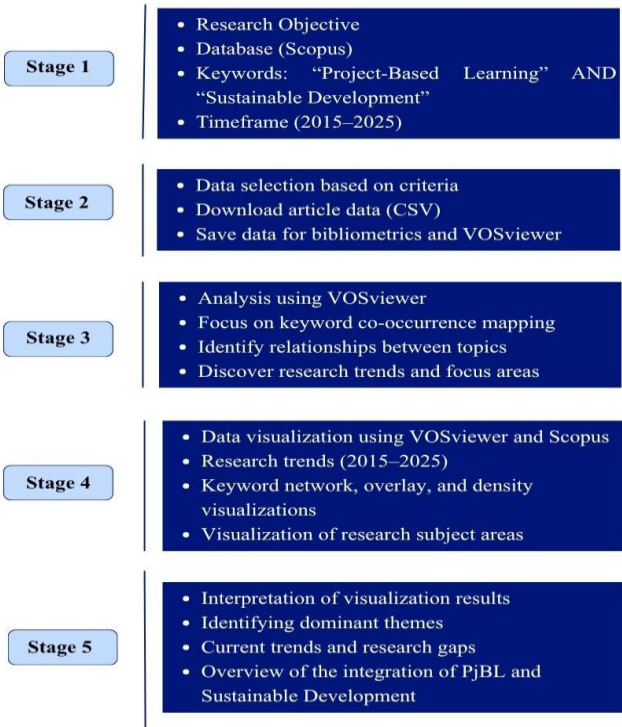


Figure 1. Stages in Bibliometric Analysis Research

The data processing stage was carried out after all metadata was obtained from the scopus database. The metadata, exported in CSV format, was first processed using Microsoft Excel and Notepad to verify, select, and normalize keywords. This process was carried out to remove irrelevant data, correct inconsistencies in spelling, and merge terms that have the same meaning but are written differently. These steps were taken to ensure the data is more accurate, consistent, and better able to represent the relationships between concepts. Once the process is complete, the metadata is ready for use in the bibliometric analysis stage.

The metadata obtained was analyzed using VOSviewer and bibliometric software. VOSviewer was used to visualize networks, while bibliometric analysis was used to examine the publication output of authors, institutions, countries, and journals, as well as trends in research topics. The analysis results are presented in the form of network visualizations, overlay visualizations, and density visualizations to illustrate collaboration patterns, relationships between keywords, research trends over time, and the density of research topics. Furthermore, the visualization results are interpreted descriptively to identify publication trends, intellectual structures, and the direction the research landscape of the integration of PjBL and ESD.

RESULTS AND DISCUSSION

Results

The results of the bibliometric analysis were used to identify the characteristics of research trends on the integration of PjBL and ESD through an analysis of publication productivity, distribution, collaboration among authors, institutions, and countries, publication sources, and research topic mapping. All findings were then comprehensively interpreted to explain research trends, relationships among concepts, and opportunities for further research. Furthermore, this analysis offers a comprehensive perspective on the intellectual structure and thematic evolution of this research domain. Furthermore, it provides valuable implications for researchers, educators, and policymakers by identifying emerging research directions and supporting the broader implementation of the integration of PjBL and ESD in educational practice.

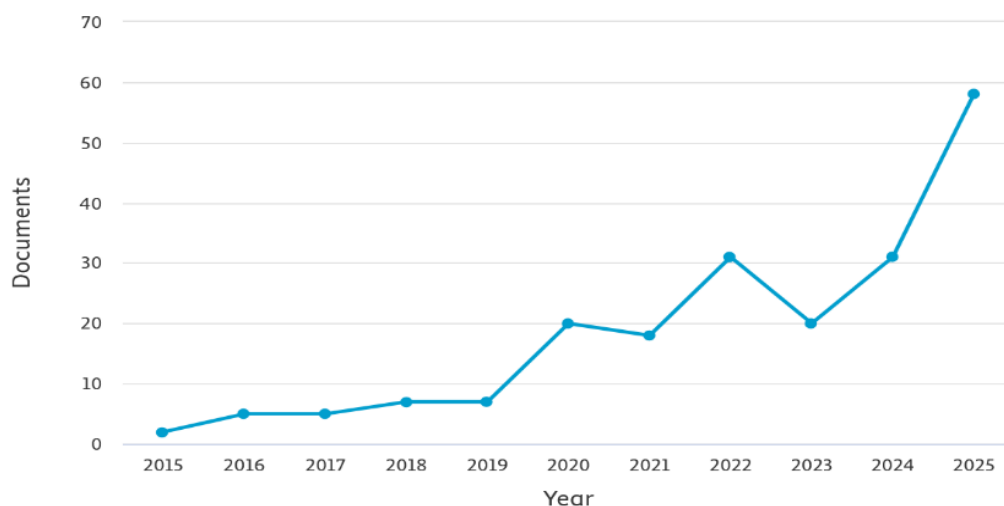


Figure 2. Distribution of Publication Trends 2015 to 2025

The figure 3 trend of scientific publications on the integration of Project- PjBL and ESD increased between 2015 and 2025. From 2015 to 2019, the number of publications grew gradually, indicating that the topic was beginning to attract attention in research. In 2020, there

was a more significant increase compared to the previous year, although a slight decline occurred. The research trend continued in 2022, then experienced a temporary decline in 2023. Publications rose again in 2024 and reached their peak in 2025. Overall, the pattern shows that research on the integration of PjBL and ESD continues to grow despite fluctuations in some years, reflecting the increasing academic attention to this topic in recent years. This increasing publication trend suggests that the integration of PjBL and ESD has become an emerging research focus in response to the growing demand for educational approaches that promote sustainability competencies and twenty-first-century skills. The continuous growth in scholarly output also reflects the expanding recognition of PjBL as an effective pedagogical approach for implementing ESD across various educational contexts. Furthermore, the upward trend indicates that this research area remains dynamic and offers substantial opportunities for future investigations, particularly in exploring innovative instructional strategies, interdisciplinary applications, and the long-term impact of PjBL on ESD.

The second finding is a keyword co-occurrence analysis visualized using VOSviewer software. The visualization provides an overview of the relationships between keywords that appear together in scientific publications, thereby identifying the conceptual structure of the research field under study. In the visualization map, each node represents a single keyword, while the connecting lines indicate the degree of relationship or the frequency of co-occurrence between keywords in the analyzed documents. The color differences among each group of nodes indicate the formation of several clusters, each depicting closely related research themes or focuses. Through this network visualization, it is possible to identify relationships among research topics, dominant themes, and the direction of research developments regarding the integration of PjBL and ESD from 2015 to 2025.

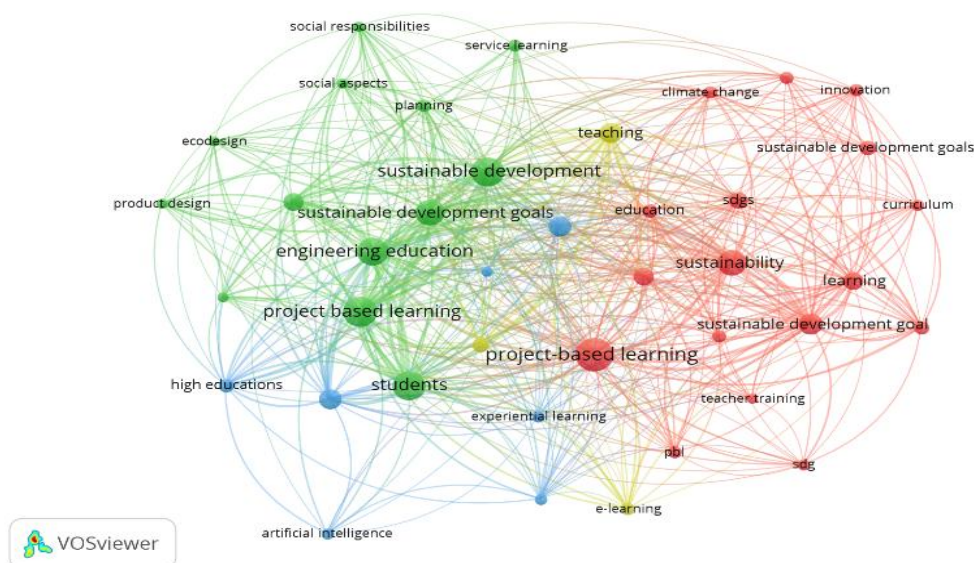


Figure 4. Visualization of the Integration of PjBL and ESD in Education

Based on the Figure 3 visualization of research on the integration of PjBL and ESD, the network consists of four interconnected clusters, indicating that this research area has evolved into a multidisciplinary field with strong conceptual relationships among various topics. The dominant positions of the keywords (PjBL), (ESD), sustainability, and (SDGs) demonstrate that these concepts form the intellectual foundation of the field and are the primary focus of research due to their high occurrence frequencies and strong link strengths. The distribution of clusters further reveals that current studies have expanded beyond pedagogical implementation to encompass engineering education, curriculum innovation, climate change education, service learning, and the integration of emerging technologies such as artificial

intelligence, reflecting the increasingly broad scope of sustainability-oriented education. The dense connections among the clusters indicate that these research themes are highly interrelated rather than independent, suggesting that the successful implementation of PjBL and ESD requires interdisciplinary collaboration among educational, environmental, technological, and social science disciplines. Overall, this network structure demonstrates that PjBL is increasingly recognized as a transformative pedagogical approach capable of operationalizing ESD by integrating authentic learning experiences with sustainability challenges, while also highlighting promising future research directions involving digital technologies and interdisciplinary educational innovation.

The third finding of this study was obtained through an overlay visualization generated using VOSviewer software. The visualization shows the temporal development of keywords based on the average year of their appearance in scientific publications regarding the integration of PjBL and ESD between 2015 and 2025. Color differences represent the time of a keyword's appearance, allowing researchers to identify topics that emerged earlier as well as themes that have recently become the focus of research. The visualization provides a comprehensive illustration of the shifts in research focus and the evolution of research directions related to the integration of PjBL and ESD over time.

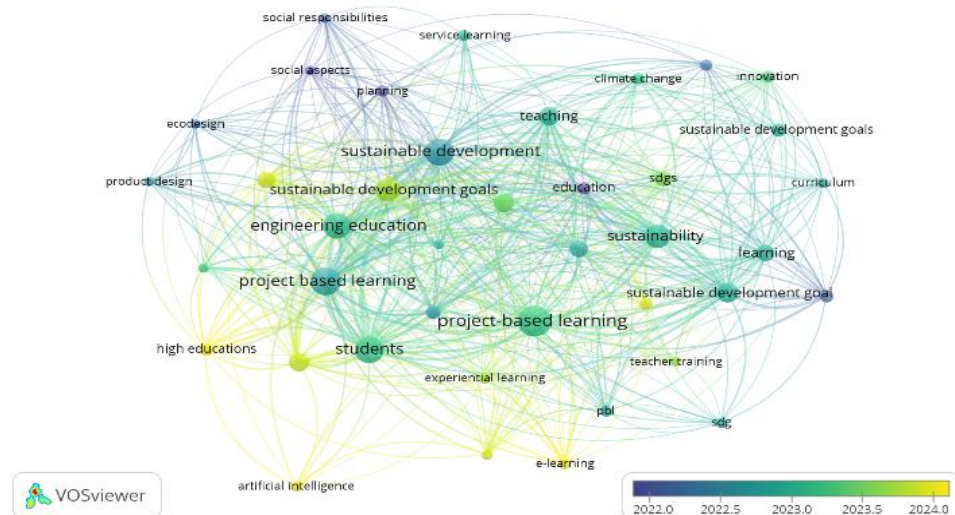


Figure 5. Visualization of the Overlap Between PjBL and ESD Integration in Education

The results in the Figure 6 show overlay visualization illustrating trends based on keywords in research on the integration of PjBL and ESD. The color differences indicate the average year of keyword emergence; blue represents topics studied earlier, while green and yellow indicate more recent topics. Based on the visualization, keywords such as PjBL, students, higher education, artificial intelligence, e-learning, and SDGs are predominantly green and yellow, indicating that these themes are the focus of recent research. Meanwhile, keywords such as sustainable development, education, learning, and social responsibilities tend to be blue to green, suggesting that these topics were developed earlier and have become the foundation for subsequent research. Overall, the visualization shows a shift in research focus toward the use of digital technology, the strengthening of higher education, and the implementation of PjBL to support the achievement of the SDGs.

The fourth finding was obtained through a density visualization generated using VOSviewer software. This visualization was employed to illustrate both the frequency of keyword occurrences and the intensity of relationships among keywords in scientific publications related to the integration of PjBL and ESD. In the density map, brighter yellow areas represent keywords with higher occurrence frequencies and stronger associations with

other keywords, whereas darker green areas indicate topics that appear less frequently and exhibit weaker relationships within the research network. The concentration of brighter areas around particular keywords reflects the existence of well-established research themes that have attracted considerable attention from the scientific community, while the darker regions suggest emerging or less extensively investigated topics. Consequently, this visualization provides a comprehensive overview of the research landscape by identifying the most influential themes, revealing the degree of interconnectedness among research topics, and indicating the relative maturity of different areas within the field. Overall, density visualization serves as an effective analytical tool for understanding the development and focus of research on the integration of PjBL and ESD, while simultaneously highlighting potential research gaps and promising directions for future studies to further advance sustainability-oriented education.

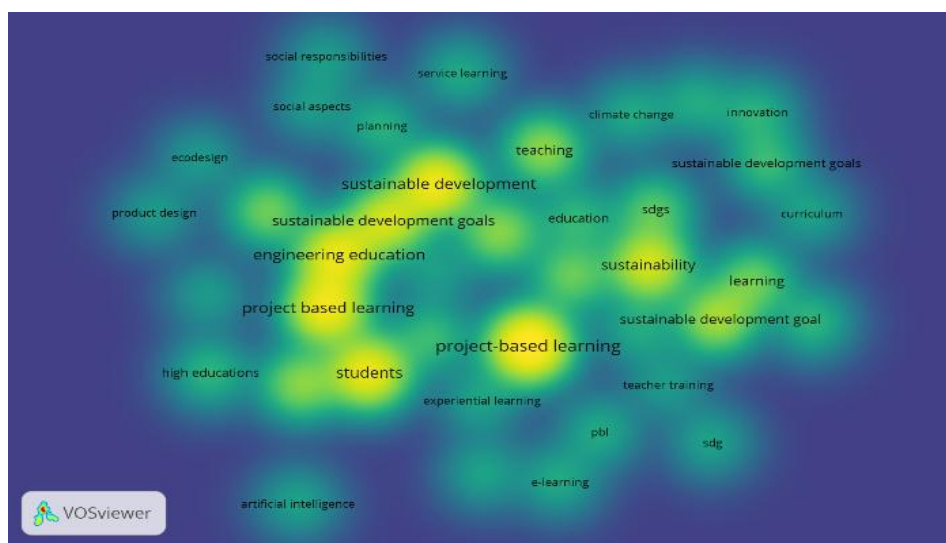


Figure 7. Visualization of the Integration of PjBL and ESD in Education

The visualization results in figure 5 show the strength of the relationships between keywords in the literature related to the integration of PjBL and ESD. The brighter the color, the higher the frequency of occurrence and the stronger the association of that keyword with other topics. Based on the visualization, the keywords Project-based learning, students, engineering education, sustainable development, sustainable development goals, and sustainability are located in the area with the highest density, indicating that they are the most frequently studied main themes and have strong connections to other research topics. Conversely, the keywords artificial intelligence, e-learning, teacher training, curriculum, and product design are located in areas of lower density, indicating that these topics are still relatively rarely studied and have the potential to become directions for future research.

The fifth finding was obtained through Analysis of the distribution of publications based on the subject area classification available in the scopus database, which illustrates the academic disciplines contributing to research on the integration of (PjBL) and (ESD) during the 2015–2025 period. Each subject area represents the relative contribution of a particular discipline to the overall publication output, providing a comprehensive overview of the dominant research fields while highlighting the involvement of various supporting disciplines. The distribution demonstrates that research on the integration of PjBL and ESD extends beyond a single academic domain and encompasses multiple disciplines with varying levels of contribution. Overall, these findings confirm that the integration of PjBL and ESD has developed into a multidisciplinary research field, reflecting the collaborative roles of educational, environmental, technological, and social sciences in advancing ESD.

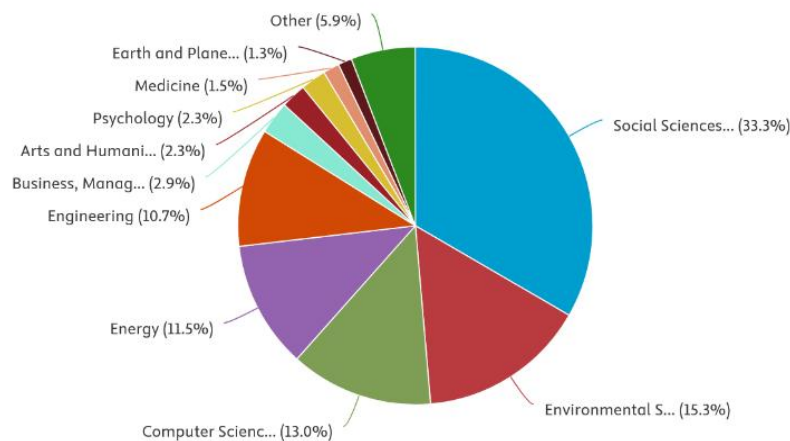


Figure 8. Distribution of Research Fields on the Integration of PjBL and ESD in Education

Based on the figure 9 show visualization, the Social Sciences dominate the number of publications with a share of 33.3%, followed by Environmental Sciences at 15.3%, Computer Science at 13.0%, Energy at 11.5%, and Engineering at 10.7%. Meanwhile, the fields of Business, Management, and Accounting; Arts and Humanities; Psychology; Medicine; and Earth and Planetary Sciences make relatively smaller contributions. This indicates that research on the integration of PjBL and ESD is not only growing within the field of Education but is also expanding into various other disciplines. This situation indicates that studies on the integration of PjBL and ESD are multidisciplinary in nature, thereby connecting various fields of study and supporting the ESD.

The sixth finding is a visualization of the distribution of publications by country or region indexed in the Scopus database. The visualization shows each country's contribution to scientific publications on the integration of PjBL and ESD from 2015 to 2025. Based on the analysis, Spain is the country with the highest number of publications, followed by the United States, Indonesia, Germany, and Australia. Meanwhile, China, Malaysia, Portugal, Taiwan, and Denmark also contributed to the development of this research, albeit with relatively fewer publications. This indicates that research on the integration of PjBL and ESD has expanded globally, involving various countries, thereby reflecting the international scientific community's growing attention to the development of learning approaches that support ESD.

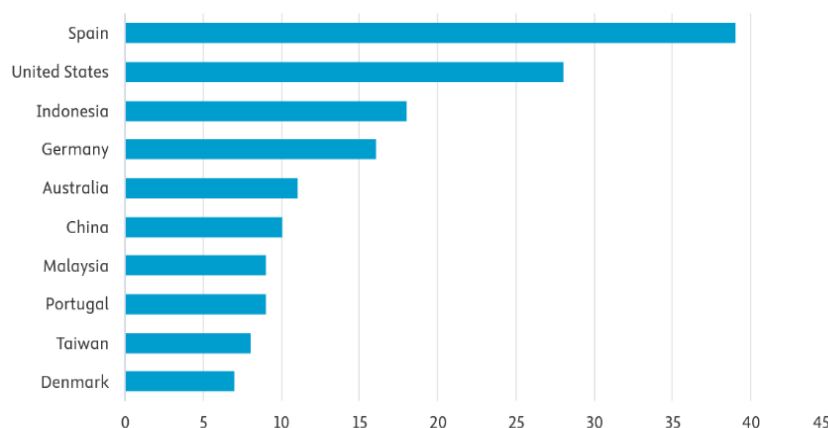


Figure 10. Distribution of Country Publications on the Integration of PjBL and ESD

Based on national contributions regarding the integration of PjBL and ESD for 2015–2025. According to the graph, Spain is the country with the highest number of publications, totaling 39 documents, followed by the United States with 28 documents; Indonesia ranks

third with 18 documents, followed by Germany with 16 documents, Australia with 11 documents, China with 10 documents, Malaysia with 9 documents, Portugal with 9 documents, Taiwan with 8 documents, and Denmark with 7 documents. The dominance of Spain and the United States indicates that these two countries place a high priority on research into the integration of PjBL and ESD, while Indonesia's third-place ranking suggests that such research is also developing rapidly in the Asian region. Overall, the distribution of publications shows that research on the integration of PjBL and ESD has expanded globally.

Discussion

The results of the bibliometric analysis show that research on PjBL and ESD has grown quite rapidly from 2015 to 2025. The increase in the number of publications in recent years indicates that this topic is gaining more attention from the scientific community as a learning approach capable of addressing the demands of 21st-century education. Although there have been fluctuations in some years, the upward trend in publications suggests that the integration of PjBL and ESD continues to evolve as a field of study relevant to the development of students' sustainability competencies. Accordingly, the implementation of ESD is increasingly becoming a priority in education because it plays a crucial role in fostering critical thinking, collaboration, and a sense of responsibility toward sustainability, while PjBL has proven effective as a sustainable project-based learning approach. This is also consistent with findings from other studies showing that ESD-based PjBL can enhance students' creative thinking, collaboration, and sense of responsibility toward sustainability issues (Melindawati et al., 2025; Purnamasari et al., 2024).

Network visualization analysis shows that the keywords PjBL, ESD, students, sustainability, dan engineering education are the themes with the strongest connections within the research network. The interconnections among these keywords indicate that research on the integration of PjBL and ESD is developing in a multidisciplinary manner by linking aspects of learning, sustainability, curriculum, and the development of student competencies. These findings are supported by research Hikmah et al, (2023) states that the implementation of the PjBL model can improve higher-order thinking skills, science literacy, and problem-solving abilities because students are actively involved in completing real-life projects. Similar results were also reported by Donthu et al, (2021) which explains that co-occurrence analysis can identify the conceptual structure of a research field through the most dominant relationships among keywords. The difference is that the study Hikmah et al, (2023) focuses on the effectiveness of PjBL implementation in physics education, whereas this study identifies the conceptual relationships between PjBL and ESD research topics at the global level through bibliometric mapping.

The results of the overlay visualization reveal a shift in the focus studies on the integration of PjBL and ESD during the 2015–2025 period. At the beginning of the research period, studies focused more on basic concepts such as education, learning, and sustainable development, whereas in the more recent period, research has shifted toward artificial intelligence, e-learning, higher education, and the SDGs. This shift indicates that research on PjBL and ESD is beginning to leverage advancements in digital technology to support more innovative and adaptive learning that meets the needs of today's education system. These findings are consistent with the research Sumilat et al, (2023) which explains that the implementation of PjBL continues to evolve by integrating digital technology to improve the quality of learning. These findings are also supported by Hallinger dan Nguyen (2020) which states that developments in ESD research indicate a shift in focus from conventional learning toward technology-based learning innovations and interdisciplinary collaboration in response to global challenges.

The results of the density visualization show that the keywords PjBL, students, ESD, sustainability, and sustainable development goals has the highest density, making it the main theme in research on the integration of PjBL and ESD. This high density indicates that most research still focuses on the implementation of PjBL as a learning approach that supports the attainment of sustainability competencies and 21st-century skills. This finding is consistent with research Yani et al, (2024) states that bibliometric research can identify dominant themes, which can then serve as a basis for determining opportunities for future research on PjBL. These findings are also supported by research Farkhan (2025) which explains that keywords with high density reflect themes that have been widely developed, while keywords with low density indicate opportunities for research on new topics. The difference is that previous studies only mapped the development of PjBL in physics education, whereas this study expands the analysis to include the integration of PjBL and ESD, thereby providing a more comprehensive picture of the direction of global research trends.

The results of the analysis by academic discipline show that research on the integration of PjBL and ESD is dominated by the social sciences, followed by environmental sciences, computer science, energy, and engineering, indicating the multidisciplinary nature of this research. The social sciences' predominance suggests that studies on PjBL and ESD are still oriented toward the development of learning strategies, curricula, and the enhancement of student competencies, while the involvement of other fields of study demonstrates the increasingly broad application of sustainable development concepts across various disciplines. The findings of this study are consistent with those reported by Wahyudi et al., (2024) shows that research on PjBL continues to evolve through the involvement of various disciplines, such as vocational education, educational technology, collaborative learning, and developing critical thinking skills has become an essential goal of modern education. The results of this bibliometric analysis suggest that *Project-Based Learning* (PjBL) has evolved beyond its traditional role as a pedagogical approach and is now recognized as a multidisciplinary learning framework that integrates knowledge from various academic disciplines.

An analysis by country shows that Spain, the United States, and Indonesia are the countries that contributed the most publications to research on the integration of PjBL and ESD during the 2015–2025 period. The dominance of these countries indicates that the development of project-based learning that supports sustainable development has become a focus of international attention and continues to evolve through cross-national collaboration. These findings are supported by research Habibulloh, (2023) which states that Indonesia is among the countries with high publication productivity in bibliometric research on PjBL, and thus still has significant opportunities to expand international collaboration and improve the quality of scientific publications.

Although the results of the bibliometric analysis indicate that research on the integration of PjBL and ESD continues to evolve, several research opportunities still warrant attention. The mapping results show that most publications still focus on the implementation of PjBL to improve learning outcomes, critical thinking skills, and sustainability competencies, while studies integrating digital technologies such as artificial intelligence, learning analytics, and adaptive learning remain relatively limited. Furthermore, the results of the overlay visualization and density visualization show that these themes are emerging topics that still require more in-depth study. These findings are consistent with research Ding et al, (2023) emphasizes that the future development of ESD must be supported by pedagogical innovation, digital transformation, and interdisciplinary collaboration in order to address the challenges of ESD. In line with this, the research Wahyudi et al, (2024) This indicates that research on PjBL is increasingly focused on integrating technology, strengthening multidisciplinary collaboration, and developing more contextual learning models; therefore,

future research should aim to develop more innovative and practical implementations of PjBL and ESD that are aligned with the educational needs of the 21st century.

CONCLUSION

This study shows that research on the integration of PjBL and ESD has seen significant growth during the 2015–2025 period, as evidenced by the growth in the number of publications, growing collaboration among researchers, and a broadening of research themes. The results of the bibliometric analysis indicate that the research is dominated by the theme PjBL, students, ESD, sustainability, and SDGs, with a trend toward the integration of digital technology and innovative learning. In addition, research on PjBL and ESD is developing in a multidisciplinary manner, dominated by the social sciences, and involves contributions from various countries, particularly Spain, the United States, and Indonesia. The results indicate that the integration of PjBL and ESD plays a crucial role in supporting the development of learning oriented toward 21st-century competencies and sustainable development. Therefore, future research is encouraged to broaden the scope of bibliographic data sources, enhance international collaboration, and develop studies that integrate PjBL and ESD with cutting-edge learning technologies to enrich educational innovation in the future.

REFERENCES

- Adekantari, P., Su'ud, & Sukardi. (2020). The Influence of Instagram-Assisted Project Based Learning Model on Critical Thinking Skills. *Journal of Educational and Social Research*, 10(6), 315–322.
- Asrizal, A., Tho, S. W., Novitra, F., Helma, H., & Annisa, N. (2026). Modeling the Impact of Interactive Ethno-STEM Learning Materials on Students' 21st-Century Skills: A Structural Equation Modeling Approach. *Journal of Pedagogical Research*, 10(1), 176–192.
- Asrizal, Festiyed, Helma, & Feziyasti, A. (2025). Augmented Reality and Education for Sustainable Development in Science Education: Effects on Students' Essential Skills-A Systematic Literature Review. *European Journal of Educational Research*, 15(3), 795–812.
- Cordova, M. (2024). Integrating Sustainable Development Goals in English Language and Literature Teaching. *Frontiers in Education*, 9, 1–8.
- Ding, H., Rong, S., Rong, K., Tang, J., & Zhou, Z. (2023). Life Cycle Assessment-Driven Collaborative Optimization Model of Power Dry Cutting for Face-Hobbing Hypoid Gear Production. *Journal of Cleaner Production*, 385(12), 1–20.
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Marc, W. (2021). How to Conduct A Bibliometric Analysis : an Overview and Guidelines. *Journal of Business Research*, 133, 285–296.
- Du, Q., Zhao, R., Wan, Q., Li, S., Li, H., Wang, D., Ho, C. W., Dai, Z., Chen, Y., & Shan, D. (2024). Protocol for Conducting Bibliometric Analysis in Biomedicine and Related Research Using Citespace and VOSviewer Software. *Star Protocols*, 5(3), 1–19.
- Faizah, Z., Rochintaniawati, D., & Winarno, N. (2026). Implementation Strategy of Education for Sustainable Development in Science Education : A Systematic Literature Review. *Jurnal Pendidikan Sains Indonesia*, 14(1), 255–277.
- Fatmawati, N. S. D., Wulandar, W., & Irawan, N. (2026). Bridging Education Gap through Educational Innovation for Sustainable Development: A Bibliometric Analysis of the Scopus Database. *Indonesian Journal on Learning and Advanced Education*, 8(1), 95–115.

- Fernando, A. R. R., & Tajan, G. P. (2024). Education for Sustainable Development (ESD) through Participatory Research (PR): A Systematic Review. *Journal of Cleaner Production*, 482, 1–12.
- Feziyasti, A., & Ashel, H. (2025). Teaching Science Mapping Research on Integration of Augmented Reality Technology and Education for Sustainable Development: A Bibliometric Analysis. *Jurnal Penelitian Pendidikan IPA*, 11(7), 12–23.
- Habibulloh, D. V. S. and M. (2023). Project Based Learning (PjBL) Model in Physics Learning: Bibliometric Analysis. *Seminar Nasional Fisika*, 7(2962–3316).
- Hadiastriani, Y., & Djarot, P. (2024). Mapping Research Trends on Development of Scientific Literacy Assessment: A Bibliometric Analysis. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 10(1), 211–222.
- Herlinawati, H., Marwa, M., Ismail, N., Liza, O., David, D., & Situmorang, B. (2024). Heliyon the Integration of 21st Century Skills in the Curriculum of Education. *Heliyon*, 10(15), 1–11.
- Hikmah, N., Febriya, D., & Mufit, F. (2023). The Impact of the Project-Based Learning Model on Students' Critical and Creative Thinking Skills in Science and Physics Learning: A Meta-Analysis. *Jurnal Penelitian Pendidikan IPA (JPPIPA)*, 9(10), 892–902.
- Hilmiatussadiah, K. G., Ahman, E., Disman, D., & Dahlan, D. (2024). Strategies for Improving 21st Century Competencies in Secondary Schools in Indonesia: A Systematic Literature Review. *Jurnal Pendidikan Progresif*, 14(3), 1914–1929.
- Holst, J., Singer-Brodowski, M., Brock, A., & de Haan, G. (2024). Monitoring SDG 4.7: Assessing Education for Sustainable Development in Policies, Curricula, Training of Educators and Student Assessment (Input-Indicator). *Sustainable Development*, 32(4), 3908–3923.
- Huang, R. X., Pagano, A., & Marengo, A. (2024). Values-Based Education for Sustainable Development (VbESD): Introducing A Pedagogical Framework for Education for Sustainable Development (ESD) Using A Values-Based Education (VbE) Approach. *Sustainability (Switzerland)*, 16(9), 2–44.
- Irawan, M. D., Tarigan, M. F. A., & Siregar, Y. H. (2024). *Analisis Bibliometrik : Pemetaan Tren Penelitian Menggunakan Aplikasi R*. Deepublish Digital.
- Melindawati, S., Sartono, E. K. E., Wuryandani, W., & Fatimah, F. (2025). Project-Based IPAS Learning to Support Sustainable Development Goals (SDGs): A Literature Review on Implementation and Impact on Environmental Awareness of Elementary School Students. *Jurnal Penelitian Pendidikan IPA (JPPIPA)*, 11(6), 29–35.
- Miller, B. T., Camarda, A., Mercier, M., Burkhardt, J. M., Morisseau, T., Bougrine, S. B., Vinchon, F., Hayek, S. El, Landais, M. A., Mourey, F., Feybesse, C., Sundquist, D., & Lubart, T. (2025). Creativity, Critical Thinking, Communication, and Collaboration: Assessment, Certification, and Promotion of 21st Century Skills for the Future of Work and Education. *Journal of Intelligence*, 11, 1–32.
- Muhamad Mi'da Farkhan, D. (2025). Project Based Learning in Physics Education: A Bibliometric Review. *EduSains*, 17 (1)(2443–1281).
- Nazifah, N., & Asrizal. (2022). Development of STEM Integrated Physics E-Modules to Improve 21st Century Skills of Students. *Jurnal Penelitian Pendidikan IPA*, 8(4), 1783–1789.
- Novita, N., Andriani, R., Muliani, M., Makfirah, H., & Nur'azizah, N. (2025). Education for

- Sustainable Development (Esd) Competency in Physics Learning Assessment: Pre-Service Teachers' Thinking Skills Based on Ethno-Socio-Scientific Content. *Jurnal Pendidikan IPA Indonesia*, 14(1), 164-180.
- Nurdiansyah, D., Ramdany, D., & Saepuzaman, D. (2026). Enhancing Students ' Scientific Literacy through Socio - Scientific Issues-Based Project-Based Learning in Physics Education. *Jurnal Pendidikan Fisika*, 14 (2)(2527-4015), 410-428.
- Öztürk, O., Kocaman, R., & Kanbach, D. K. (2024). How to Design Bibliometric Research: an Overview and A Framework Proposal. *Review of Managerial Science*, 18(11), 3333-3361.
- Page, M. D. (2021). The PRISMA 2020 Statement: an Updated Guideline for Reporting Systematic Reviews. *British Medical Journal (BMJ)*, 372, 1-8.
- Purnamasari, A. Y., Rustaman, N., Purwianingsih, W., & Lestari, W. (2024). Implementation of Project-Based Learning Containing ESD to Improve Students ' Creative Thinking Skills. *Jurnal Penelitian Pendidikan Indonesia (JPPI)*, 10(4), 110-117.
- Rahmawati, J., Masykuri, M., & Utomo, S. B. (2025). A Systematic Literature Review and Bibliometric Analysis of Education for Sustainable Development Integration in Science Education and its Unaddressed Gaps. *Journal of Environment and Sustainability Education*, 3(4), 561-574.
- Sumilat, J. M., Ilam, D., Vanesa, M., Mangantibe, A. C. M., Mukuan, E., Kumontoy, N., Guru, P., Dasar, S., Manado, U. N., Mukuan, E., & Kumontoy, N. (2023). Analisis Implementasi Model PjBL (Project Based Learning). *Jurnal Basicedu*, 7(6), 3980-3988.
- Syafri, S. (2026). Trends and Future Directions in Computational Studies of DSSCs: A Systematic Bibliometric Study. *Multidisciplinary Reviews*, 10, 1-15.
- Wahyudi, Y., Widiaty, I., & Yulia, C. (2024). Identifikasi Pendekatan Project Based Learning dalam Konteks Pembelajaran di Pendidikan Vokasional: Analisis Bibliometrik. *Jurnal Penelitian Pendidikan*, 24 (3)(2541-4135), 421-451.
- Yani, I. P., Festiyed, & Asrizal. (2024). Bibliometric Analysis : Using E-Modules Based on Project Based Learning in Physics Learning. *Journal of Innovative Physics Teaching (JIPT)*, 2(1), 62-70.
- Zulaika, A., Erlina, & Rachmat Sahputra. (2022). Research Trends About Education for Sustainable Development (ESD) in Science Learning: A Bibliometric Analysis During 2014-2024. *Jurnal Pendidikan MIPA*, 12(1), 1-7.