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Science Mapping Research of the Integration of PjBL Model and STEM Approach: A Bibliometric Analysis

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ABSTRACT

Integration of Project-Based Learning (PjBL) with the Science, Technology, Engineering, and Mathematics (STEM) approach has gained increasing attention in science education due to its potential to develop 21st-century skills. However, studies examining the development and research directions of the integration of these two approaches have not yet been comprehensively mapped. This study aims to analyze trends, collaboration patterns, and thematic focuses in research related to the integration of PjBL and STEM in science education. This study employs a bibliometric approach using data obtained from Scopus-indexed articles published between 2015 and 2025. The analysis was conducted using VOSviewer through performance analysis, co-authorship, keyword co-occurrence, and thematic mapping. The results indicate a significant increase in the number of publications, with primary focuses on the development of 21st-century skills, student engagement, and contextual learning. Research collaboration remains relatively limited but is beginning to expand internationally. The integration of PjBL and STEM has been shown to contribute to the creation of interactive and meaningful science learning. This study provides valuable insights as a foundation for developing innovative learning strategies and guiding more integrated future research directions.

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INTRODUCTION

Development of 21st-century skills among students has become a primary focus in modern education. In this era, the education system is undergoing significant transformation, particularly in the implementation of innovative learning approaches that are capable of integrating various disciplines and developing essential student skills. Effective learning approaches can enhance student engagement, encourage collaboration, and develop higher-order thinking skills (Feziyasti et al., 2025; Ulmi & Asrizal, 2024). The 21st-century skills such as critical thinking, creativity, communication, and collaboration have become key competencies that students must possess to face global challenges (Thornhill-Miller et al., 2023). With the mastery of these skills, students are expected to adapt to the increasingly complex development of science and technology.

The learning process must be designed to optimally facilitate the development of 21st-century skills. Learning in the modern era needs to be oriented toward student-centered activities, contextual learning, and the application of approaches that promote active engagement (Goodwin, 2024). The current education system requires the implementation of contextual, project-based learning models that are oriented toward the development of character and 21st-century competencies (Hasan et al., 2025). In this regard, project-based learning approaches and interdisciplinary integration become essential elements in supporting meaningful learning. Furthermore, learning that connects concepts with real-world problems in students' environments is a key characteristic of 21st-century education.

The integration of project-based learning approaches with the STEM (Science, Technology, Engineering, and Mathematics) approach is one of the important strategies in 21st-century science education. The Project-Based Learning (PjBL) model enables students to learn through direct experience in completing projects that are relevant to real-life contexts (Amiri, 2025). Meanwhile, the STEM approach encourages the integration of interdisciplinary knowledge to solve complex problems systematically (English, 2023). The implementation of the STEM approach in science learning contributes to improving students' conceptual understanding and scientific literacy, especially in abstract topics (Asrizal et al., 2025). Therefore, the integration of the PjBL model with the STEM approach has the potential to create more contextual, applicable, and skill-oriented learning that supports the development of 21st-century competencies.

Independent Curriculum is one of the educational policies in Indonesia that supports the implementation of innovative, project-based learning and STEM integration. This curriculum provides flexibility for educators to design learning experiences that align with students' needs and characteristics (Alfaeni et al., 2023). Learning within the Independent Curriculum emphasizes the strengthening of the Pancasila Student Profile, which includes critical thinking, creativity, collaboration, and independence. Therefore, the integration of the PjBL model with the STEM approach is relevant to be implemented in science learning to support the achievement of curriculum objectives.

However, various studies indicate that students' 21st-century skills are still relatively low. Critical thinking, creativity, and collaborative skills have not yet developed optimally (Muawiyah, 2024; Sari et al., 2025). This condition is caused by learning processes that remain teacher-centered and the limited implementation of innovative learning models capable of developing these skills (Nisa et al., 2024). In addition, the implementation of interdisciplinary learning approaches is still not optimal in practice. This situation highlights the need for learning innovations that can effectively address these challenges.

The PjBL model is one of the solutions that can be applied to improve the quality of science learning. This model emphasizes active student involvement in completing authentic and meaningful projects (Crawford et al., 2024). PjBL enables students to develop critical thinking, creativity, and collaborative skills through processes of exploration and investigation (Fitriani et al., 2025). Moreover, PjBL can also enhance students' learning motivation by providing more engaging and relevant learning experiences connected to real-life situations.

The STEM approach also plays an important role in improving the quality of science learning. This approach integrates science, technology, engineering, and mathematics into a unified learning framework (Portillo-Blanco et al., 2025). STEM-based learning encourages students to think systematically, creatively, and innovatively in solving real-world problems (Kaya-Capocci et al., 2025; Suherman et al., 2025). In addition, the STEM approach not only contributes to improving learning outcomes but also strengthens students' higher-order thinking skills (Asrizal et al., 2024). Therefore, the integration of PjBL with STEM is believed to provide more comprehensive and meaningful learning experiences.

Various studies have shown that the integration of PjBL with STEM has a positive impact on learning. This integration can enhance students' critical thinking, creativity, and problem-solving skills (Azzahra et al., 2025; Indranuddin et al., 2024). In addition, PjBL-STEM-based learning can also increase student engagement and provide deeper and more contextual learning experiences (Ospankulova et al., 2025). Therefore, this integration is considered one of the effective learning innovations in 21st-century science education.

Although numerous studies on PjBL and STEM have been conducted both separately and in an integrated manner, studies that specifically map the development of research on the integration of PjBL with STEM in science education remain limited. Most previous studies have focused more on the effects of implementation on learning outcomes without comprehensively examining research trends, researcher collaboration, and the development of research themes (Usman et al., 2026). This limitation indicates a research gap that needs to be further explored through a systematic and comprehensive approach.

Bibliometric analysis is an effective method for mapping the development of research in a particular field. This method enables researchers to identify publication trends, collaboration networks, and dominant research topics (Maryadi et al., 2025). By using bibliometric analysis, this study seeks to examine the development of research on the integration of PjBL with STEM in science education over recent years. The results of this analysis are expected to provide a comprehensive overview of research directions as well as future research opportunities.

This study aims to map the research landscape of science education that integrates the PjBL model with the STEM approach through bibliometric analysis. Specifically, this study aims to analyze publication growth and map research themes through network visualizations such as co-occurrence, overlay visualization, and density visualization. This study is expected to contribute strategic insights for researchers, educators, and policymakers in developing more innovative and relevant research and learning practices aligned with 21st-century needs. Furthermore, the findings of this study are expected to serve as a foundation for future research agendas and to strengthen the implementation of PjBL-STEM integration as an innovation in science education.

METHODS

This study employs a bibliometric analysis method to map the development of research related to the integration of the PjBL model with the STEM approach in science education. This method is a quantitative approach used to describe, evaluate, and systematically trace the development of scientific publications (Zupic & Čater, 2015). Through this approach, the analysis is conducted objectively and measurably, thereby minimizing subjectivity that often arises in qualitative studies (Aria & Cuccurullo, 2017). In addition, bibliometric analysis enables researchers to identify collaboration patterns, research topic trends, and the dynamics of publication development within the field under study (Donthu et al., 2021).

The data source in this study was obtained from the Scopus database, which is widely recognized for its extensive coverage of internationally reputable scientific publications. The selection of Scopus was based on the completeness of its metadata and the quality of the indexed journals. The search process was limited to publications from 2015 to 2025 to capture the development of research over the past decade. The types of documents analyzed include articles, review articles, and conference reviews. All retrieved data were then systematically screened to ensure their relevance to the research focus.

The selection of keywords was conducted carefully to ensure that the retrieved literature was truly relevant to the topic under investigation. The keywords used consisted of a combination of terms related to Project-Based Learning, STEM, and science education, such as "project-based learning" AND "STEM" AND "science." The use of the Boolean operator AND was intended to refine the search results, making them more specific and aligned with the research objectives. This keyword selection strategy was designed to ensure that the collected articles adequately represent the relationship between the implementation of the PjBL model and the STEM approach within the context of science learning.

The research procedure was carried out through several systematically structured stages to ensure clarity in the analysis process. These stages follow the bibliometric analysis framework proposed by Donthu et al. (2021), which includes data collection, article selection based on inclusion criteria, data processing, bibliometric analysis, visualization of results, and interpretation of findings. Each stage was designed to produce valid data in accordance with the research objectives. Through this process, only relevant articles that meet scientific criteria were included in the analysis. The research framework is presented in the form of a diagram to provide a clearer overview of the overall research workflow.

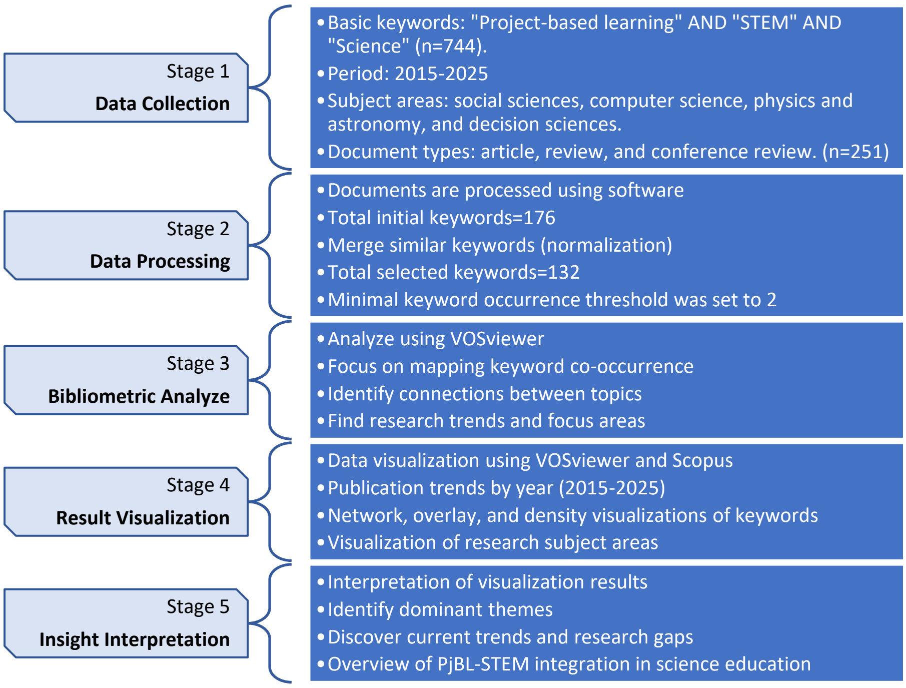

Figure 1. Stages in Bibliometric Analysis Research

In the data processing stage, this study utilized several supporting software tools to ensure the accuracy of the analysis results. The data obtained from Scopus were first processed using Microsoft Excel and Notepad. This stage included keyword normalization and reduction, which involved merging terms with similar meanings but different forms of expression. Subsequently, the cleaned data were visualized using VOSviewer software. The selection of VOSviewer was based on its ability to generate interactive and easily interpretable visualizations, thereby facilitating the identification of patterns and relationships among the data.

The data analysis was conducted by utilizing metadata obtained from Scopus and importing it into VOSviewer. The analysis focused on keyword occurrences and relationships among documents to identify the structure and trends of the research field. The results were visualized in the form of network visualization, overlay visualization, and density visualization. These three types of visualizations were used to identify thematic clusters, temporal development of research, and the intensity of specific topics. The interpretation of the results was carried out descriptively by referring to the patterns observed in the visualizations. In addition, information regarding publication trends and subject areas was also obtained from the analysis of data available in the Scopus database.

RESULTS AND DISCUSSION

Results

The results of this study present several key findings obtained through bibliometric analysis related to the integration of the Project-Based Learning (PjBL) model with the STEM approach in science education. The first finding of this study is the analysis of scientific publication trends over the past ten years. The data visualization was obtained from the Scopus database using keywords relevant to PjBL and STEM to illustrate the dynamics of research growth from year to year. These results provide an initial overview of the development and intensity of academic attention toward the integration of PjBL and STEM within the context of science education.

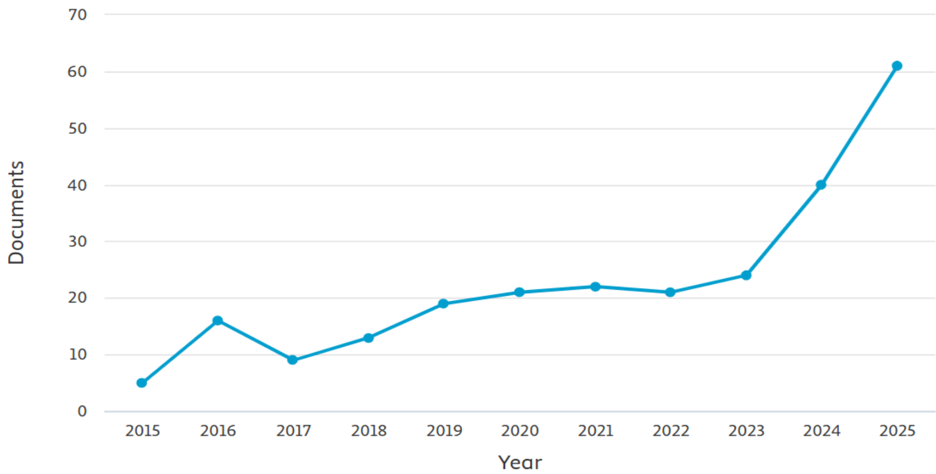

Figure 2. Distribution of Publication Growth from 2015 to 2025

The trend of scientific publication growth related to the integration of the PjBL model with the STEM approach in science education during the period 2015–2025 is presented in Figure 2. In general, there is a noticeable upward trend in the number of publications, although some fluctuations occur in certain years. In the early period (2015–2017), the number of publications was relatively low and unstable, indicating that this topic was still in its initial stage of development. A more consistent increase began to emerge during the period 2018 to 2021, reflecting the growing interest of researchers in the integration of PjBL and STEM. Although a slight decline occurred in 2022, the trend rose again in the following years, with a significant surge in 2024 and reaching its peak in 2025. This pattern indicates that the topic of PjBL-STEM integration continues to develop and gain broader attention in science education research.

The second finding of this study was obtained through network visualization analysis from bibliometric mapping generated using VOSviewer software. This visualization illustrates the structure of relationships among keywords based on co-occurrence, where each node represents a keyword, while the connecting lines indicate the level of association between keywords. The different colors of the nodes indicate clustering into specific groups that represent related research themes. In this study, all keywords derived from the VOSviewer mapping are presented in italics to distinguish them from the explanatory text and to emphasize that they represent specific terms identified in the bibliometric analysis. Through this visualization, patterns of relationships, network density, and the distribution of research themes in the integration of the PjBL model with the STEM approach in science education can be identified.

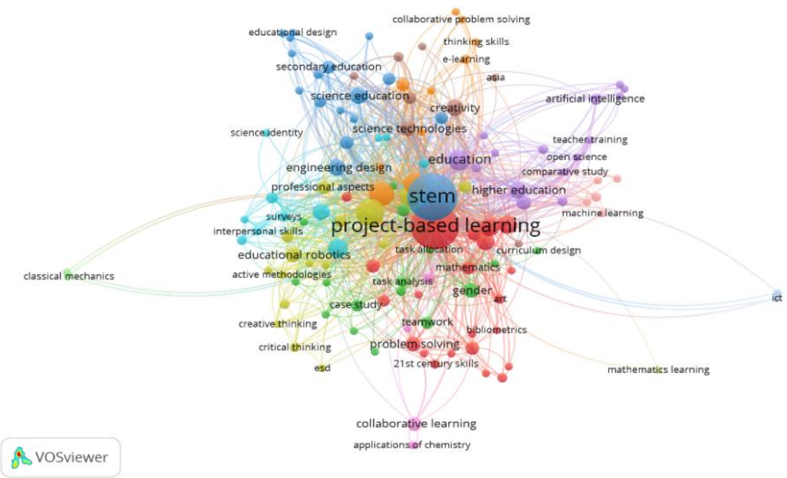

Figure 3. Network Visualization of the Integration of PjBL with STEM in Science Education

Based on the network visualization diagram, the keywords *project-based learning* and *STEM* appear as the central nodes with the largest sizes, reflecting their high frequency of occurrence and strong level of interconnectedness. Surrounding these nodes, a green node without a label represents *science education*, positioned close to the center of the network, emphasizing its role as the primary research context. The network structure indicates the presence of three main interconnected clusters. The first cluster relates to 21st-century skills, including *student*, *problem solving*, and *critical thinking*. The second cluster focuses on the integration of technology in learning, including *technology*, *engineering*, and educational innovation. The third cluster is associated with sustainability issues, such as *energy*, *climate change*, and *sustainability*. Meanwhile, keywords such as *physics module* and *ICT* are located at the periphery of the network, indicating a relatively lower level of connectivity compared to the main themes.

The third finding is the overlay visualization analysis, which illustrates the temporal development of keywords in studies on the integration of PjBL with STEM in science education. The color of each node represents the average publication year in which a keyword frequently appears in the literature. All keywords derived from the VOSviewer mapping are presented in italics to indicate that they represent the keywords analyzed in this study. This visualization provides insights into the dynamics of research development and shifts in research focus over time.

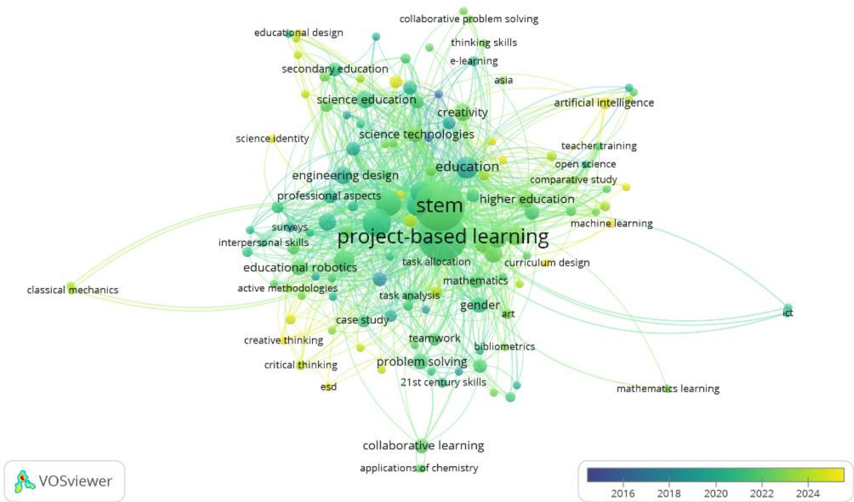

Figure 4. Overlay Visualization of the Integration of PjBL with STEM in Science Education

The overlay visualization results in Figure 4 show that the keywords *PjBL* and *STEM* have the largest node sizes and occupy central positions in the network, indicating their roles as the main themes in integrated learning studies. The keyword *science education* appears in close proximity to PjBL and shares strong connections within the context of science education research. Additionally, PjBL and STEM show development during the mid-to-recent periods, as indicated by the dominant colors in the middle to later stages of the network visualization. In the early period, research primarily focused on keywords such as *educational computing*, *online learning*, and *communication*, reflecting an emphasis on basic learning technologies. In the intermediate phase, there is a growing emphasis on 21st-century skills, highlighted by keywords such as *problem solving*, *critical thinking*, and *collaboration*. In the most recent period, the research focus shifts toward more contextual and global issues, including *sustainability*, *climate change*, *SDGs*, as well as the integration of advanced technologies such as *artificial intelligence*, *educational robotics*, and *immersive technology*. Overall, this visualization indicates a shift in research focus from basic learning technologies toward more complex, contextual, and globally oriented STEM-based learning integration.

The fourth finding of this study is the density visualization analysis of the bibliometric data. Density visualization is used to illustrate the level of density or intensity of keyword occurrences within the analyzed publication dataset. Brighter colors indicate keywords with high frequency and strong associations with the research topic, while darker colors represent lower levels of occurrence and connectivity. All keywords derived from the VOSviewer mapping are presented in italics to indicate that they represent the keywords analyzed in this study. Through this visualization, core keywords that serve as the main focus in studies on the integration of the PjBL model with the STEM approach in science education can be identified.

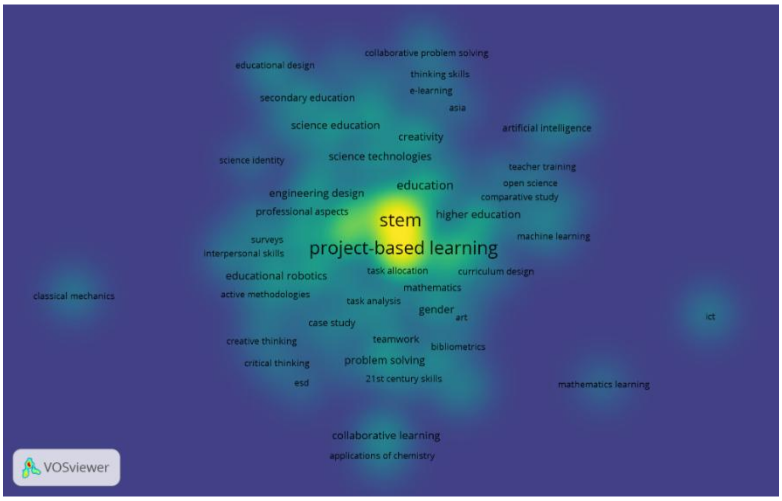

Figure 5. Density Visualization of the Integration of PjBL with STEM in Science Education

The visualization results in Figure 5 show the intensity of relationships among keywords in the literature related to the integration of PjBL and STEM. Areas highlighted in bright yellow indicate keywords with very high occurrence and strong interconnections, while green and blue areas represent lower levels of association. The keywords *PjBL* and *STEM* are positioned at the center of the map with the highest density, indicating that these two concepts are the primary focus of the research. In addition, the keyword *student* appears close to the high-density center, suggesting that research in this field is strongly oriented toward students as the main subjects of learning. Other keywords such as *technology*, *engineering*, *collaboration*, and *problem solving* are located in the yellow-green zone, indicating a strong relationship between PjBL-STEM integration and the development of 21st-century skills. Meanwhile, keywords such as *artificial intelligence*, *educational robotics*, *climate change*, and *energy sustainability* are found in green to blue areas, reflecting emerging themes that have not yet become dominant focuses. On the other hand, keywords such as *physics module* and *ICT* are located at the periphery of the map, indicating relatively lower connectivity to the core research themes.

The fifth finding of this study is the subject area visualization. This visualization illustrates the distribution of disciplines involved in publications related to the integration of the PjBL model with the STEM approach in science education. Each category represents the relative contribution of a particular field to the development of the research area. This information is useful for understanding dominant disciplinary directions as well as the multidisciplinary nature of PjBL-STEM studies.

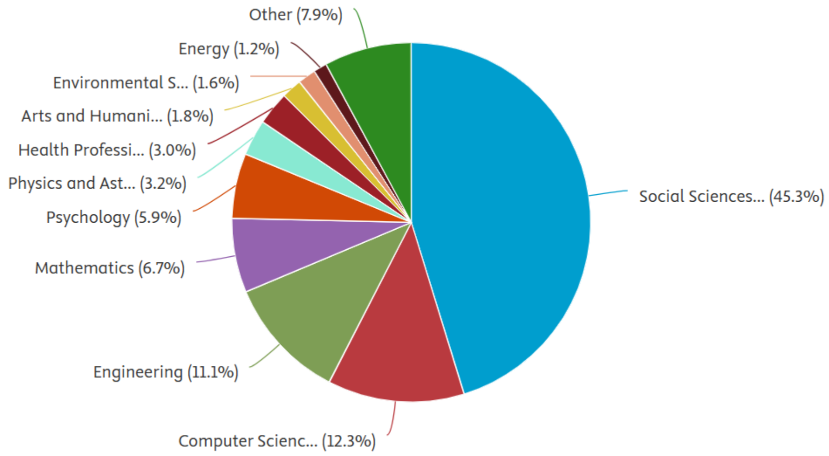

Figure 6. Subject Area Distribution of Research on the Integration of PjBL with STEM in Science Education

Based on the subject area distribution in Figure 6, Social Sciences occupies the dominant position with 224 documents or approximately 45.3% of the total publications, indicating that research is largely focused on educational and social aspects in the implementation of STEM-based PjBL. Furthermore, Computer Science (12.3%) and Engineering (11.1%) also make significant contributions, reflecting the close relationship between technology and engineering within the STEM approach. The fields of Mathematics (6.7%) and Psychology (5.9%) also demonstrate important roles, particularly in supporting cognitive aspects and problem-solving processes in learning. Meanwhile, Physics and Astronomy account for only 3.2%, followed by Health Professions at 3.0%, indicating that contributions from pure science disciplines are relatively smaller. Other fields such as Arts and Humanities, Environmental Science, and Energy each contribute less than 2%, showing limited but existing involvement in this research area. In addition, fields such as Chemistry, Agricultural and Biological Sciences, and Neuroscience have very low publication counts, reflecting that research in these areas is still relatively scarce. Overall, these data indicate that research on the integration of PjBL with STEM is more concentrated in the domains of education and technology, with more limited contributions from specific science disciplines.

Discussion

The increasing trend of publications related to the integration of Project-Based Learning (PjBL) with the STEM approach during the period 2015–2025 indicates a shift from an exploratory phase toward consolidation as a primary instructional approach in science education. In the early stage, the low number of publications reflects the complexity of interdisciplinary integration as well as the limited readiness of teachers and curricula, which are indeed major challenges in STEM implementation (Li et al., 2020). The consistent increase in subsequent years suggests the growing body of empirical evidence supporting the effectiveness of PjBL-STEM in enhancing higher-order thinking skills, student engagement, and conceptual understanding through authentic learning experiences (Kokotsaki et al., 2016). This is further supported by findings that project-based learning in a STEM context can simultaneously integrate knowledge and practice, resulting in more meaningful learning (Condliffe, 2022). Thus, this trend reflects not only quantitative growth in publications but also the consolidation of PjBL-STEM as an approach aligned with the demands of 21st-century education.

The network visualization structure reveals that PjBL and STEM function as the intellectual core, integrating various research themes, with *science education* serving as the main context that connects them. This finding confirms that the integration of PjBL-STEM has evolved into a dominant conceptual framework in science learning, rather than merely a combination of two approaches. The dominance of the 21st-century skills cluster, including *problem solving* and *critical thinking*, indicates that the research focus has shifted toward the development of complex competencies central to constructivist learning (Kurt & Akoglu, 2023). Furthermore, the connection with the technology cluster suggests that technology acts as a key enabler in effective STEM implementation (Hasanah, 2020). This finding is consistent with studies indicating that effective STEM integration requires synergy among content, pedagogy, and technology within a unified instructional design (Thibaut et al., 2018).

The findings from the overlay visualization demonstrate an evolution in research focus from basic learning technologies toward more complex and contextual learning integration. In the early phase, the dominance of keywords such as *educational computing* and *online learning* reflects an emphasis on the digitalization of learning as a response to technological advancements. Subsequently, the focus shifted toward strengthening 21st-century skills, before evolving further into global issues such as *sustainability* and *climate change*, indicating increasing awareness of the importance of real-world contexts in learning (Li et al., 2022). In addition, the emergence of advanced technologies such as *artificial intelligence* and *educational robotics* signifies that STEM learning continues to adapt to digital technological developments (Zhai et al., 2021). This shift indicates that PjBL-STEM is evolving not only conceptually but also contextually in addressing global challenges.

The results of the density visualization further reinforce that *PjBL*, *STEM*, and *student* are located in the highest-density areas, indicating a strong research orientation toward students as the center of learning. The strong connections with keywords such as *collaboration* and *problem solving* emphasize that this approach consistently aims to develop essential 21st-century skills (Thibaut et al., 2018). This aligns with social constructivist theory, which highlights the importance of social interaction in the learning process. On the other hand, the presence of keywords such as *artificial intelligence* and sustainability-related issues in lower-density areas suggests that the integration of advanced technologies and global contexts is still in a developing stage (Holmlund et al., 2018). This condition indicates opportunities for expanding the integration of these topics in future research.

The subject area distribution shows the dominance of Social Sciences, indicating that research on the integration of PjBL-STEM is more focused on pedagogical aspects rather than in-depth exploration of specific science disciplines. Contributions from Computer Science and Engineering demonstrate that technology and engineering serve as essential pillars in the implementation of STEM. However, the relatively low contribution from pure science fields such as physics and chemistry suggests that the application of PjBL-STEM within specific content areas remains limited. This finding is consistent with studies indicating that much of STEM research still operates at the level of general instructional design rather than deep disciplinary content integration (Li et al., 2022). Therefore, more research focusing on the development of discipline-based instructional materials is needed.

Despite showing significant development, the findings of this study also identify several gaps that require attention. Limitations in the implementation aspect, particularly in the development of learning materials grounded in specific science disciplines, indicate that research is still dominated by conceptual approaches. In addition, the integration of advanced technologies such as artificial intelligence and robotics remains suboptimal, while the lack of longitudinal studies limits understanding of the long-term impact of PjBL-STEM implementation (Zhai et al., 2021). Previous studies have also emphasized the importance of long-term evaluation to comprehensively assess the effectiveness of project-based learning (Kokotsaki et al., 2016). Therefore, future research should be directed toward developing more applicable, contextual, and sustainable learning models to bridge the gap between theory and practice.

CONCLUSION

Based on the results of the data analysis, five main conclusions can be drawn. First, publications in this field show a consistent growth trend and increasing relevance in the context of 21st-century learning, particularly in efforts to develop critical thinking, creativity, and problem-solving skills. Second, the mapping of thematic clusters indicates a strong relationship between project-based pedagogical approaches and the integration of STEM disciplines, which together support contextual and problem-oriented learning. Third, the overlay visualization results reveal that current research trends focus on strengthening the implementation of PjBL-STEM to enhance 21st-century skills as well as the utilization of technology in science learning. Fourth, the density visualization shows that the most dominant keywords are centered on PjBL, STEM, and science education, confirming these as the core focus of the field, although there remain opportunities for the development of more specific subtopics. Fifth, the subject area analysis demonstrates that this research is multidisciplinary, with major contributions from the fields of education, social sciences, as well as science and technology. Overall, these findings confirm that the integration of the PjBL model with the STEM approach has significant potential to drive innovation in science learning that is more meaningful, adaptive, and relevant to the demands of contemporary developments.

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