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Project-Based Learning and Ethno-STEM in Enhancing Science Literacy and Critical Thinking: A Systematic Review

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Abstract: The purpose of this research is to examine the trend in the development of studies integrating the approaches of Project-Based Learning (PjBL) and EthnoSTEM to improve critical thinking skills and science literacy among students from 2016 to 2025. The issues identified in this research relate to the development of scientific publications that combine these three approaches and their contribution to enhancing skills relevant to the demands of the 21st century. The method applied is descriptive analysis with a bibliometric approach, using data obtained from Google Scholar, which was then analyzed using Publish or Perish (PoP) software and Dimensions.ai, and visualized using VOSviewer. The analysis results show a significant increase in publications addressing the theme of integrating PjBL, Ethno-STEM, science literacy, and critical thinking, especially after 2020, with the most dominant form of publication being book chapters. The keyword visualization confirms that the main focus of research in modern science education is geared towards the development of innovative learning models, improvement of critical thinking skills, and science literacy. Based on these findings, this research recommends further development of the integration of ethno-STEM and project-based approaches to support the quality of 21st-century learning.

Keywords: Ethno-STEM; Science literacy; Crithical thinking; Project Based Learning

Introduction

21st Century Skills, including creative thinking, critical thinking, and problem-solving, communication, and collaboration (4C), are now essential competencies that Indonesian students must master in order to adapt and compete in the ever-changing global era (Syahidi et al., 2023; Zakaria, 2021; Oktariani et al., 2020; Yuningsih, 2019). These four skills, which are part of Higher Order Thinking Skills (HOTS), have become a main focus in the development of modern education, as emphasized by the Partnership for 21st Century Skills (Verawati et al., 2020). To develop the 4C, innovations in learning are crucial, one of which is integrating technology as a learning resource to enrich student experiences and make the learning process more interactive (Ernest, 2023). Moreover, science literacy is an important foundation for students to access, evaluate, and effectively utilize information amidst the challenges of the digital era. Recent studies have proven that learning approaches that emphasize interactivity and local cultural relevance can enhance student motivation and understanding (Adhelacahya et al., 2023; Sumarni & Kadarwati, 2020).

The Ethno-STEM approach provides students with the opportunity to study science through the lens of local culture, making learning more meaningful. By combining Project-Based Learning (PjBL) and Ethno-STEM, it is expected that a learning environment will be created that encourages critical thinking and enhances science literacy. STEM is an integrated learning approach that teaches students through the combination of various disciplines—science, technology, engineering, and mathematics—without separating subjects in the traditional manner (Brown et al., 2011). This approach focuses on creating contextual and

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applied learning experiences, allowing students to relate the concepts learned to real-life situations. Winarni et al. (2016) emphasize that STEM-based learning combines elements of science, innovation, design, and mathematics to stimulate students' imagination and critical thinking abilities. In line with this, Sukmana (2018) states that STEM is an effective global learning strategy because it emphasizes the integration of these four fields to create a relevant and engaging learning process.

Science literacy is a fundamental aspect that indicates a person's involvement in science issues and understanding of scientific concepts and processes as a reflective citizen (Alatas & Fauziah, 2020). PISA identifies four key aspects of science literacy: context, competence, knowledge, and attitudes (Izzatunnisa et al., 2019), which are crucial in shaping individuals who can explain scientific phenomena, design and evaluate investigations, and interpret data accurately (Suryaningrum et al., 2021). Science literacy is very important to be taught, particularly at the elementary and secondary levels, as it helps students solve problems effectively (Chusni & Hasanah, 2018; Jufrida et al., 2019).

Science education plays a major role in shaping superior human resources by developing critical thinking skills, communication, technological mastery, and adaptation to change (Nurkaenah et al., 2019). Therefore, science literacy learning should be directed toward the utilization of knowledge to understand and respond to various real-life situations. Project-Based Learning (PjBL) has become one of the prominent pedagogical approaches in modern education, especially for developing 21st-century skills. PjBL places students at the center of the learning process, where they collaboratively work on long-term projects that require the application of knowledge and skills to solve real problems. Unlike traditional methods that tend to emphasize memorization and passive learning, PjBL emphasizes hands-on experiences, inquiry, and problem-solving as the core of the learning process. Numerous studies have shown that the consistent implementation of PjBL can enhance students' critical thinking, collaboration, and communication skills, which are crucial competencies in today's globalized and technologically advanced world (Sari et al., 2020; Sumarni & Kadarwati, 2020; Putra & Rahmawati, 2022; Rahmawati et al., 2023). Moreover, PjBL encourages the development of creativity, adaptability, and the ability to work collaboratively in diverse groups, making it highly relevant to prepare students for the challenges of modern society (Izzati et al., 2021; Pratiwi et al., 2025).

In the context of science education, PjBL offers an innovative method that actively engages students in exploring scientific concepts through projects that mimic actual scientific inquiry processes. Through this approach, students are encouraged to design experiments, collect and analyze data, and present their findings, allowing them to practice the scientific method in a real and contextual manner (Apriliani et al., 2019; Sari et al., 2022). PjBL aligns with the primary goal of science education, which is not only to provide factual knowledge but also to foster critical thinking skills and the ability to evaluate scientific evidence rationally. By focusing on the application of knowledge rather than mere memorization, PjBL has been proven to enhance students' problem-solving abilities and deepen their understanding of scientific principles (Rahmawati et al., 2023; Sumarni & Kadarwati, 2020).

Although the effectiveness of PjBL in enhancing student engagement and learning outcomes has been well-established, its implementation in science education remains an evolving research topic. Recent studies highlight the positive impact of PjBL on improving students' critical thinking skills and academic achievement in science (Doyan et al., 2024; Han et al., 2022; Pratiwi et al., 2025). Students engaged in PjBL generally show significant improvements in problem-solving abilities and understanding of scientific concepts compared to students in traditional learning settings (Izzati et al., 2021; Sari et al., 2020). Moreover, PjBL also supports the development of collaborative skills, which are crucial for success in the modern workforce (Putra & Rahmawati, 2022; Rahmawati et al., 2023).

This study aims to analyze trends in the use of Project-Based Learning (PjBL), Ethno-STEM, critical thinking skills, and science literacy from 2016 to 2025. Using a bibliometric approach, this study identifies key themes, publication sources, and dominant keywords related to PjBL in science education. The findings will provide an up-to-date overview, uncover under-researched areas, and recommend future research directions to optimize the role of PjBL and Ethno-STEM in the development of critical thinking and problem-solving skills. Overall, this study contributes to the PjBL literature with in-depth bibliometric analysis while providing valuable information for educators and policymakers to improve science education quality and prepare students for the challenges of the 21st century.

Method

This study employed a descriptive–analytical research design to systematically identify, examine, and describe research trends related to the integration of Project-Based Learning (PjBL) and Ethno-STEM in enhancing students' critical thinking skills and scientific literacy. The descriptive approach was used to capture the overall patterns, characteristics, and developments of publications over time, while the analytical

component enabled deeper interpretation of thematic relationships and conceptual emphases within the selected studies. This design is appropriate for trend analysis and systematic reviews, as it allows for both quantitative mapping of publication data and qualitative interpretation of research focuses.

The data source for this study was Google Scholar, selected due to its broad coverage of peer-reviewed journals, conference proceedings, and academic publications. Data retrieval was conducted using Publish or Perish (PoP) and Dimension.ai to ensure comprehensive and structured bibliographic extraction. The search strategy employed relevant keywords, including *project-based learning*, *Ethno-STEM*, *critical thinking skills*, and *scientific literacy*, either individually or in combination. The inclusion criteria comprised publications indexed by Google Scholar between 2016 and 2025, resulting in a total of 500 documents that met the predefined relevance and quality criteria for further analysis.

To analyze the data, this study utilized VOSviewer software to visualize bibliometric networks, including keyword co-occurrence, thematic distribution, and research density. The visualization results were interpreted using a quantitative bibliometric approach to identify dominant themes and research clusters. Furthermore, qualitative content analysis was applied to selected articles to examine how PjBL and Ethno-STEM were conceptually integrated and linked to students' critical thinking and scientific literacy outcomes. The combination of bibliometric visualization and qualitative analysis enabled a comprehensive understanding of both the structural trends and the substantive focus of the existing literature.

Result and Discussion

This study aims to describe research trends related to the integration of project-based learning, Ethno-STEM, critical thinking skills, and scientific literacy from 2016 to 2025. The analysis focused on publication trend graphs based on keywords, publication types, the top ten reference sources, the top ten authors, and popular keywords. These trends were evaluated using the Dimensions.ai platform. Furthermore, data obtained from Google Scholar and processed through the Publish or Perish (PoP) application were further analyzed using VOSviewer software, which includes three main types of visualizations: keyword networks, overlays, and distribution density.

Based on publication data from Dimensions.ai, the number of scientific publications each year meeting the criteria related to project-based learning, Ethno-STEM, critical thinking, and scientific literacy from 2016 to the projected year 2025 shows a consistent upward trend. In 2016, there were approximately 90 publications, and this number gradually increased, peaking at around 305 publications in 2024. This increase indicates a growing attention and interest in academia regarding the integration of these four concepts in educational research, particularly in STEM fields and the development of critical thinking skills and scientific literacy. This suggests that topics such as project-based learning, the incorporation of local cultural knowledge (Ethno-STEM), and the development of critical thinking and scientific literacy skills are increasingly recognized as important areas for curriculum development and innovative learning strategies.

Meanwhile, the data for 2025 shows a sharp decline in the number of publications, most likely due to the data for that year being partial or incomplete as the year had not yet ended when the data was collected. Therefore, the publication numbers for 2025 cannot be considered as an indication of the actual trend. Overall, this graph illustrates that research on project-based learning, Ethno-STEM, critical thinking, and scientific literacy has grown rapidly over the past decade, demonstrating the relevance and urgency of these topics in modern education and the demands of the 21st century. These findings also provide a foundation for researchers and policymakers to understand the evolution of research and guide future research focus or educational policies.

Gumilar et al. (2022) found that Ethno-STEM research in Indonesia, particularly in primary school science education, is growing with the integration of project-based learning models and local wisdom approaches, which have proven effective in enhancing students' critical and creative thinking skills. This finding is supported by Rini's study (2025), which, through a bibliometric analysis from 2014 to 2024, highlights the increasing trend of research related to ethnoscience, scientific literacy, and the development of innovative learning models based on local culture.

Figure 1 uses Dimensions.ai. In Dimensions, the keywords used are project-based learning, Ethno-STEM, critical thinking, and scientific literacy. The data retrieved amounted to 38,564 for all research fields, and when narrowed down to the field of Education, the number of results was 2,352. The annual research data shows a trend of increasing studies from 2016 to 2024. In 2016, the number of studies was recorded at 90. In the following year, 2017, this number increased to 103 studies. This upward trend continued in 2018 with 153 studies, and then further rose to 169 in 2019. The year 2020 also saw an increase, with 186 studies.

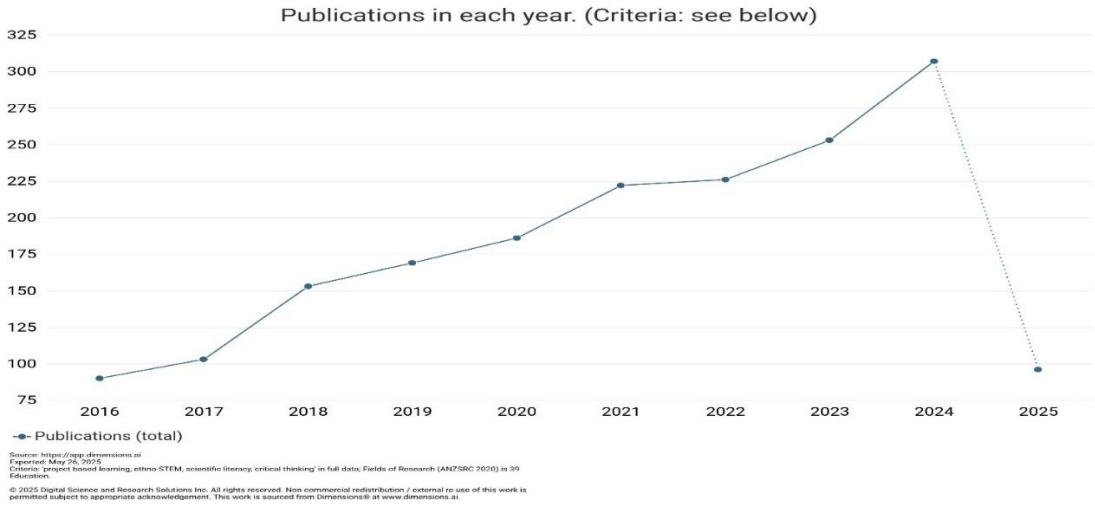

Figure 1. Research Trends in PjBL, Ethno-STEM, Science Literacy, and Critical Thinking

Subsequently, in 2021, the number of studies rose to 222, and in 2022, it slightly increased to 226. The year 2023 marked a more noticeable rise with 253 studies, and the peak occurred in 2024, with the number of studies reaching 307. This increase reflects the growing interest and focus on this research topic over the period. However, in 2025, there was a sharp decline, with only 97 studies, likely due to incomplete data or external factors affecting the conduct of research in that year. Overall, this data illustrates a significant growth in the number of studies year over year. Based on Dimensions.ai publications, the top 10 researchers with the most publications have been presented in Table 1.

Tabel 1. Top 10 Researchers with the Most Publications Related to PjBL, Ethno-STEM, Science Literacy, and Critical Thinking Research

Author/Affiliation	Number of Publications
North-West University	41
Sudarmin	13
Woro Sumarni	10
Josef J. De Beer	9
Tomi Apra Santosa	8
Adri Du Toit	6
Neal T. Petersen	6
Jako Olivier	6
Ellianawati	5
Asrizal	5
Agung Tri Prasetya	5

The publication data shows that North-West University ranks highest with 41 publications, indicating the institution's role as a center for academic collaboration in the field of education, particularly in relation to STEM and ethnoscience. At the individual level, Sudarmin (13 publications) and Woro Sumarni (10 publications) from Indonesia, as well as Josef J. de Beer (9 publications) from South Africa, are the leading researchers actively involved in international research collaborations. Contributions from other researchers, such as Tomi Apra Santosa (8), Adri du Toit, Neal T. Petersen, and Jako Olivier (6 each), further strengthen the interdisciplinary dimension in the development of innovative learning models. Researchers like Ellianawati, Asrizal, and Agung Tri Prasetya (5 publications each) have also contributed to the development of education based on local wisdom and technology.

Overall, this publication pattern reflects the synergy between institutions and individuals in driving innovation and contextualizing education relevant to the needs of the times. Based on Dimensions.ai, research publication trends can also be found in areas such as PjBL, ethno-STEM, science literacy, and critical thinking, as presented in Table 2.

Table 2. Trends in Research on PjBL, Ethno-STEM, Science Literacy, and Critical Thinking

Publication Type	Number of Publications
Edited Book	1018
Monograph	604
Article	505
Chapter	202
Proceeding	12
Preprint	11
Jumlah	2352

The publication data shows that edited books are the most prevalent, with a total of 1,018 publications, indicating that edited volumes serve as the primary medium for disseminating scholarly works. Following this, monographs account for 604 publications, reflecting a focus on in-depth and comprehensive studies on specific topics. Scientific articles reach 505 publications, demonstrating intensive research activity and the dissemination of research findings in a more concise and systematic form. Book chapters also make a significant

contribution, with 202 publications, as part of collective volumes discussing various specific themes. Meanwhile, publications in the form of proceedings and preprints remain limited, with only 12 and 11 publications respectively, indicating that formal publications with a peer-review process are the primary focus of this collection. Overall, the distribution of publication types reflects a strong academic orientation toward scholarly works in the form of books and articles, with an emphasis on the depth of analysis and quality of presentation.

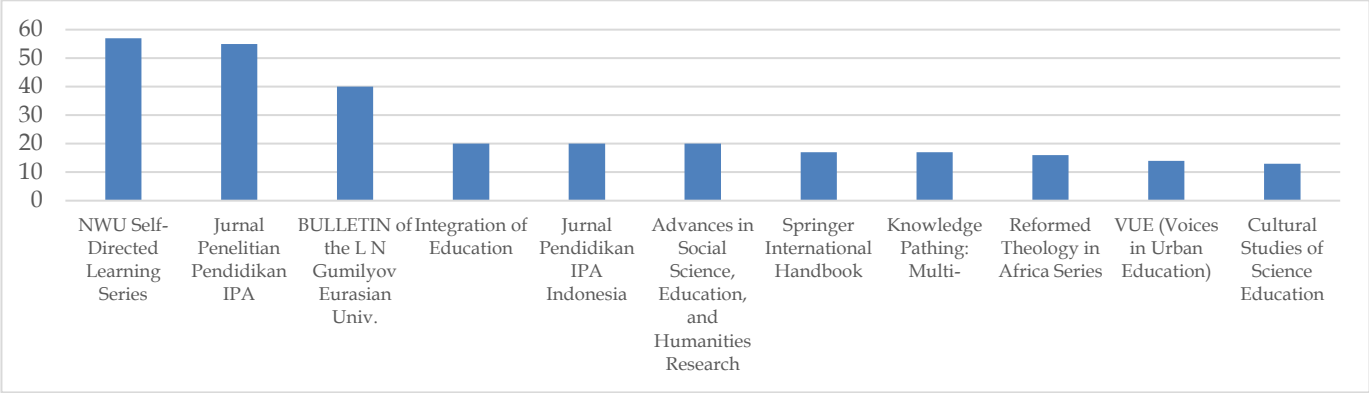

Figure 2. Sources of Publications on Research Trends in PjBL, Ethno-STEM, Science Literacy, and Critical Thinking

The graph illustrates the distribution of publications based on publication sources, with the NWU Self-Directed Learning Series and the Jurnal Penelitian Pendidikan IPA as the top two sources, each producing 57 and 55 publications, respectively, indicating the dominance of these sources in academic contributions. The next source, the BULLETIN of the L N Gumilyov Eurasian University, has a significant number of publications, totaling 40, while other sources such as Integration of Education, Jurnal Pendidikan IPA Indonesia, and Advances in Social Science, Education, and Humanities Research each produce 20 publications. Other sources, including the Springer International Handbook, Knowledge Pathing: Multi-, Reformed Theology in Africa Series, VUE (Voices in Urban Education), and Cultural Studies of Science Education, show smaller contributions, with publication numbers ranging from 13 to 17. Overall, this distribution reflects a strong concentration of publications in a few key sources, while other sources contribute more limited yet still important roles in the framework of academic knowledge dissemination.

Figure 3 illustrates a network map depicting the relationships between concepts in the academic context, specifically in the field of education. This map represents a type of co-existence diagram or semantic network, where each node (keyword) is connected by lines indicating the degree of association or the frequency of co-occurrence within a specific research dataset or collection.

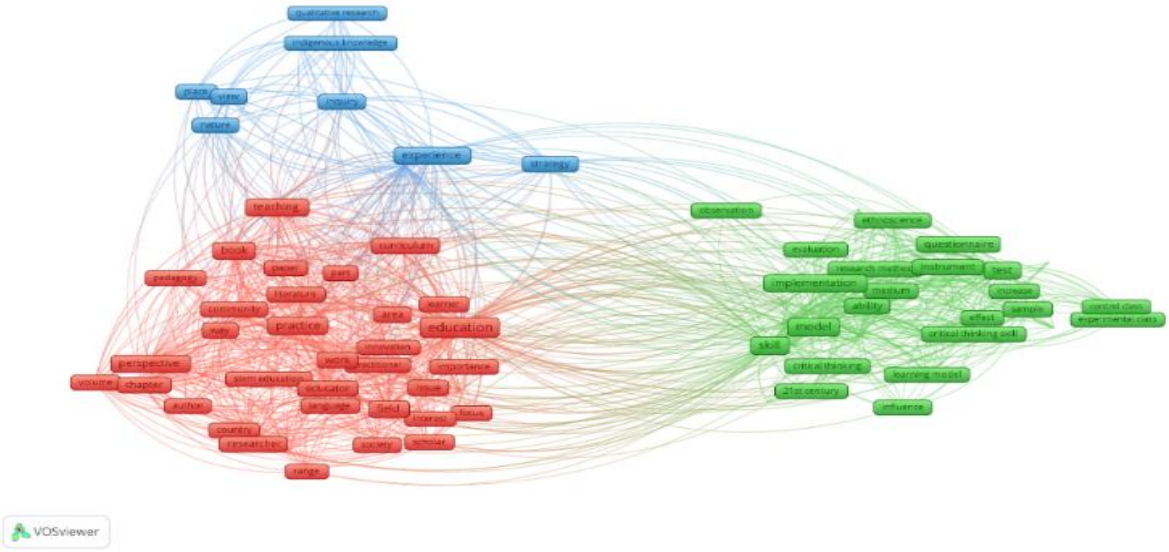

Figure 3. Network Visualization of Research Trends in PjBL, Ethno-STEM, Science Literacy, and Critical Thinking

Three distinct color clusters (red, green, and blue) represent the division of keywords into specific thematic areas. The red cluster, focusing on education, includes terms such as "education," "teaching," "practice," "book," "perspective," and "research," indicating a focus on educational theory, practices, and research related to the learning environment and teaching methods. The green cluster, centered on data and modeling, encompasses words like "model," "implementation," "questionnaire," "data," "evaluation," and "learning model," highlighting research methodologies related to data analysis, modeling techniques, and tools used in the educational context. The blue cluster, with words such as "experience," "strategy," and "curriculum," leans more towards strategic planning in education, with an emphasis on the experiences of learners or practitioners within the educational system. Overall, this image provides a visual representation of the key themes in educational research, emphasizing the connections between theory, data analysis, and practical applications.

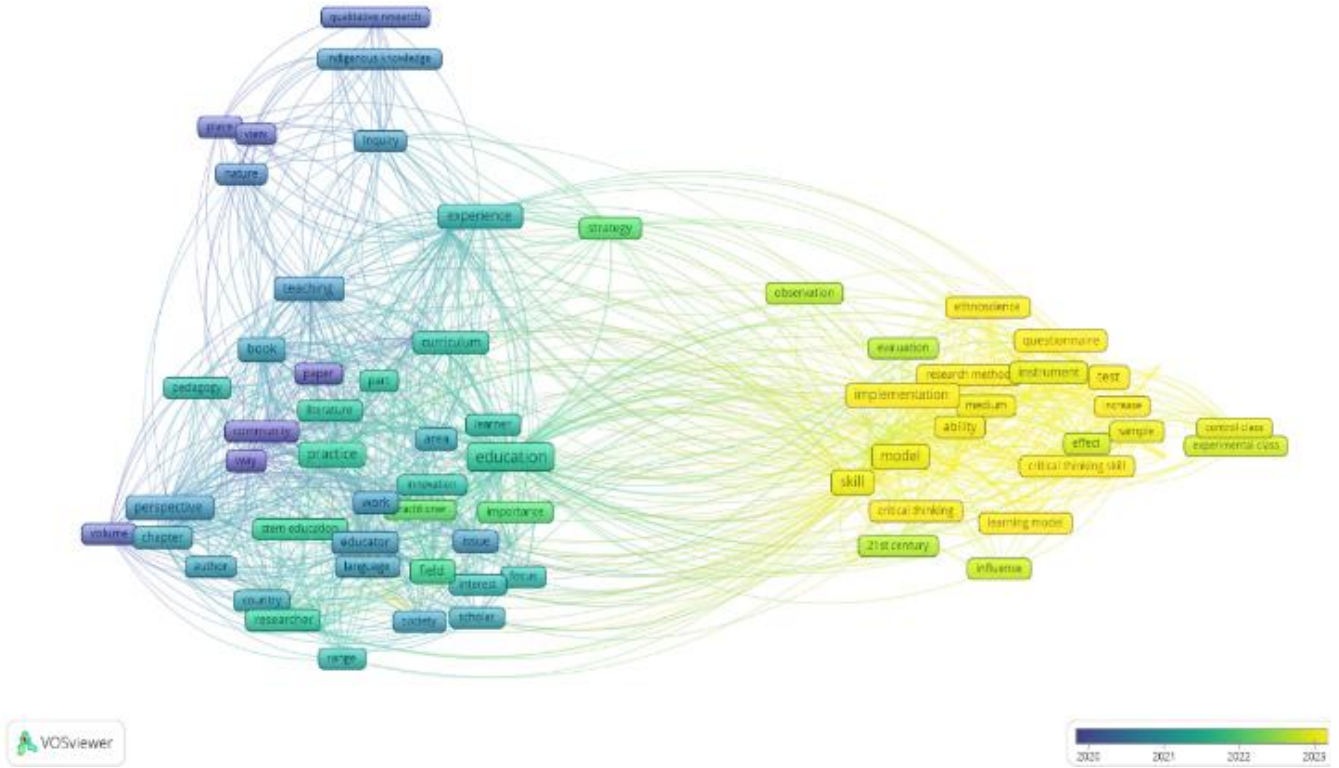

Figure 4. Overlay Visualization of Research Trends in PjBL, Ethno-STEM, Science Literacy, and Critical Thinking

The keyword overlay visualization generated using VOSviewer software, as shown in the image above, provides a comprehensive overview of the development and research trends in the fields of STEM education, science literacy, and the development of critical thinking skills from 2020 to 2023. The colors in this network represent the publication timeline, where blue and purple clusters indicate research themes that emerged earlier, while green to yellow clusters represent topics that have developed and become the focus of current research.

On the left side of the visualization, the blue and purple clusters are dominated by keywords such as "qualitative research," "indigenous knowledge," "nature," "teaching," "practice," "curriculum," and "pedagogy." These keywords reflect the initial research focus on curriculum development, learning practices, as well as the integration of local knowledge and qualitative methods in science education. Researchers during this period explored the foundations of pedagogy, the role of teachers, literature, and contextual approaches that emphasized the experiences and cultural knowledge in the learning process. As time progressed, the visualization shifts towards the green cluster, which acts as a transitional bridge between fundamental research and learning innovations. Keywords such as "education," "experience," "strategy," "field," and "educator" begin to dominate, signaling a shift towards the application of more varied and relevant teaching strategies in response to the needs of learners in the modern era. During this phase, researchers began to focus on the importance of learning experiences, implementation strategies, and the role of educators in adapting learning innovations.

The far-right section of the visualization is dominated by yellow, indicating the most recent research topics such as "critical thinking," "skill," "model," "implementation," "evaluation," "instrument," "ethnoscience," "questionnaire," and "test." These keywords highlight the increased attention on the development of innovative learning models, the measurement and evaluation of 21st-century skills, as well as the application of project-based learning and ethnoscience methods. This trend emphasizes that the research focus has shifted from general and traditional educational practices to more specific studies on the development of critical thinking skills, science literacy, and contextualized approaches.

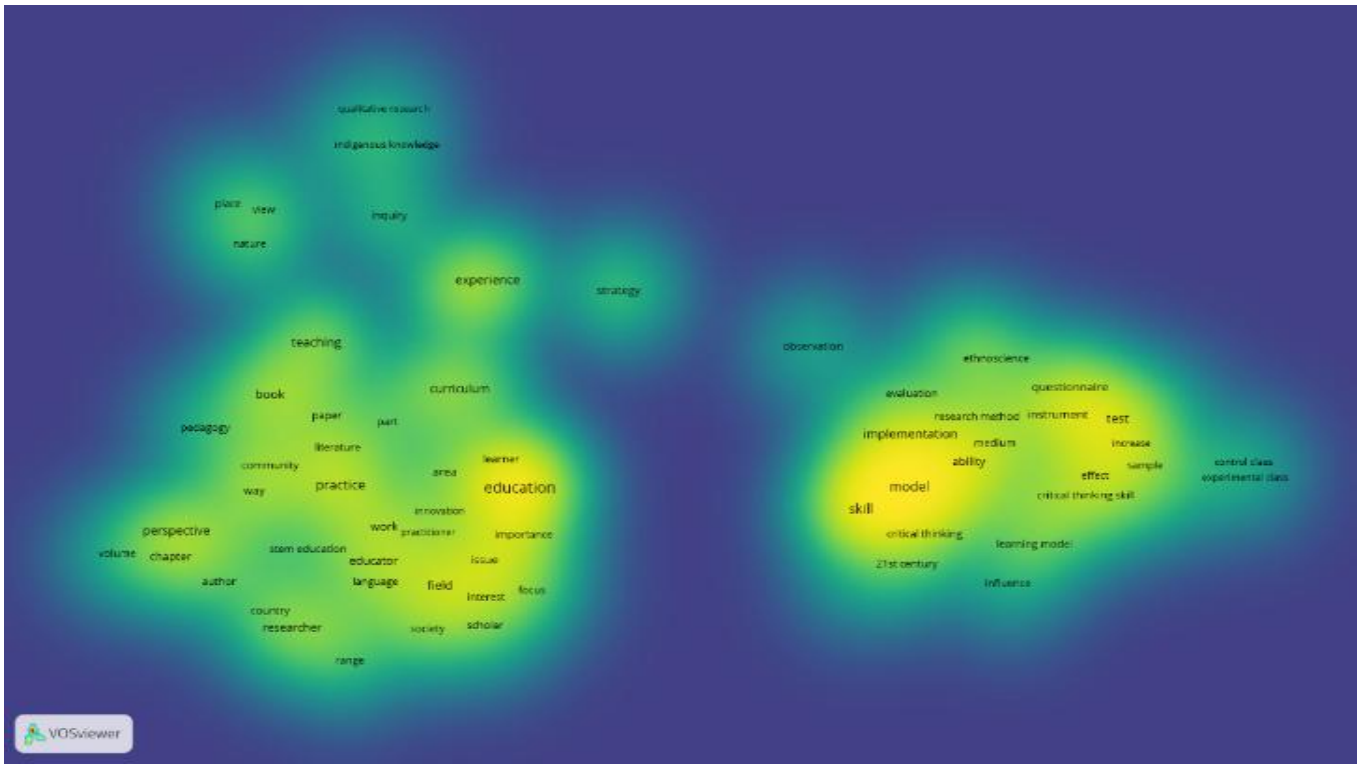

Figure 5. Density Visualization of Research Trends in PjBL, Ethno-STEM, Science Literacy, and Critical Thinking

Based on Figure 5, the keyword density visualization results using VOSviewer software specifically display the distribution and frequency of keyword occurrences in scientific publications within the fields of STEM education, science literacy, and the development of 21st-century skills. In the density visualization, the yellow color indicates keywords that appear most frequently and are the central focus of research, while the green and blue colors represent lower frequencies or more peripheral themes.

From the figure, words such as "education," "practice," "model," "implementation," "skill," "test," and "critical thinking" stand out prominently as they are located in the dense yellow area. This indicates that themes such as education, learning practices, model development, strategy implementation, skills measurement, and critical thinking evaluation have become the primary focus of scientific publications in recent years. Additionally, keywords such as "ethnoscience," "learning model," "instrument," and "evaluation" also appear frequently, signaling a strong research trend in the development of innovative learning models, integration of local knowledge, and evaluation of learning effectiveness.

Other keywords located in the green and blue areas, such as "qualitative research," "indigenous knowledge," "teaching," "curriculum," and "experience," although less dense than the yellow area, still indicate attention to qualitative approaches, integration of local wisdom, as well as curriculum development and learning experiences. Overall, this density analysis reinforces that current research is highly focused on learning model innovations, critical thinking skills assessment, and the development of science literacy that aligns with the needs of 21st-century education.

Conclusion

Research trends on Project-Based Learning (PjBL), Ethno-STEM, science literacy, and critical thinking have become highly engaging and rapidly evolving topics in educational literature. Bibliometric analysis shows a significant increase in the number of publications discussing the integration of PjBL with the development

of critical thinking skills and science literacy, especially in the context of STEM education. PjBL is considered effective in encouraging active student engagement through real-world projects relevant to life, thereby enhancing problem-solving abilities, collaboration, and the use of digital technology in modern learning.

Additionally, the Ethno-STEM approach is increasingly being adopted because it integrates local cultural values into science and technology education. This not only boosts creativity and critical thinking among students but also fosters cultural awareness and the relevance of learning to everyday life. Recent studies highlight the importance of developing culturally-based learning resources, teacher training, and infrastructure support to sustain the implementation of Ethno-STEM in schools.

Another factor driving the development of these topics is the global demand for mastering 21st-century skills such as critical thinking, science literacy, and the ability to adapt to technological changes. PjBL and Ethno-STEM are considered capable of addressing these challenges by providing a more contextual, meaningful, and applicable learning experience

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AuthorContributions
All authors have contributed to the writing of this paper.

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Conflict of Interest
All authors declare that they have no conflicts of interest.

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