

Trend Research of Problem-Based Learning to Improve Students' Science Process Skills: Article Review

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Received: 19 April, 2025

Revised: May 10, 2025

Accepted: June 25, 2025

Published: June 30, 2025

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Abstract: Problem-based learning (PBL) has been recognized as one of the effective teaching methods for improving students' critical thinking and problem-solving skills. This article aims to analyze research trends related to PBL in the context of improving students' science process skills. This study uses a bibliometric analysis method, with data taken from Google Scholar from 2015-2024 with the help of Publish or Perish, Dimensions.ai., and VOSviewer apps. The results of the analysis show that the number of documents with PBL topics and student science processes skill increased steadily from 2014-2023, and decreased slightly in 2024 (until October 18, 2024). This research also highlights the importance of integrating PBL with the Science, Technology, Engineering, and Mathematics (STEM) approach and the use of technology for 21st-century skill development. Furthermore, this study recommends that future research focus more on topics that are still less explored, such as local wisdom and inquiry approaches in science learning.

Keywords: Bibliometric analysis; Problem-based learning; Science education; Science process skills; STEM

Introduction

Problem-based learning (PBL) is a method proven effective in enhancing students' problem-solving skills (Ardianto & Rubini, 2016; Fery et al., 2017; Rachmawati et al., 2019; Suwono et al., 2023). PBL engages students in real-life situations where they analyze problems, formulate questions, and collaboratively seek solutions. Hmelo-Silver (2004) suggests that PBL not only deepens students' understanding of scientific concepts but also fosters essential interpersonal and collaborative skills. Through this approach, students connect acquired knowledge with real-world experiences, making the learning process more meaningful and relevant (Muhdhar et al., 2024).

In the 21st-century educational era, problem-solving skills have become one of the key competencies that students need to face various challenges in an increasingly complex world (Fadhilah et al., 2023; Pebriana et al., 2024). Science process skills are one of the

measures of the quality of education. In addition, the low level of knowledge of students is directly proportional to their low skills in implementing science in daily life (Sasmitatias & Kuswanto, 2018).

With the rapid development of technology and information, as well as rapid changes in various aspects of life, students are required to not only have theoretical knowledge but also the ability to think critically and creatively in solving problems (Kaufman, 2013). Therefore, innovative and effective learning approaches are needed in the context of education, especially in the field of science (Ducha et al., 2019). In improving students' literacy and science skills, it is important to use approaches that students can grasp according to the phenomena that exist around them such as the PBL method (Rachmawati et al., 2019).

This PBL model has been shown to improve students' literacy in a variety of subjects, and many researchers have developed it according to the passage of time (Wijnia et al., 2024). Therefore, this study aims to

How to Cite:

Nanisfi, M., Susilawati, S., Gunawan, G., Al Idrus, A., & Sukarso, A. A. (2025). Trend Research of Problem-Based Learning to Improve Students' Science Process Skills: Article Review. *Current Educational Review*, 1(2), 53-60. Retrieved from <https://journals.balaipublikasi.id/index.php/cer/article/view/352>

analyze research trends related to PBL in the context of improving science process skills based on the Google Scholar Database from 2015 to 2024. Using bibliometric analysis methods, this study provides insight into how PBL research has evolved during this period, as well as changes in themes and approaches used and provides a summary of future trends and research potential (Arruzza et al., 2023; Li et al., 2024).

Method

This study used bibliometric analysis with content analysis. Bibliometric analysis can effectively summarize large amounts of bibliographic data. By adding a stage of literature review methods, bibliometric analysis can reveal hidden patterns that can aid the research process, identify knowledge gaps, research patterns and trends, and new ideas for future investigation (Shuang et al., 2023).

The documents in this study were obtained from Google Scholar. There are 3 applications used in this study, namely Publish or Perish, Dimensions.ai, and

VOSviewer. Publish or Perish is used to retrieve data from the Google Scholar database which is then analyzed using VOSviewer. VOSviewer is used to map the most frequently used keywords (Table 4, Figure 2, Figure 3, Figure 4). Meanwhile, Dimension.ai is used to analyze general data, including publication trends by year (Figure 1), publication type (Table 1), the most journals (Table 2), and the number of citations based on documents (Table 3). The keywords used are "PBL AND science AND student AND skill" with a period of 2015-2024. The data was accessed on October 18, 2024.

Result and Discussion

This study analyzes the trend of applying Problem-Based Learning (PBL) in improving students' science process skills with bibliometric methods. Based on the data that has been analyzed, the results cover various aspects, ranging from the type of publication, the number of citations, and the trend of keywords used, to how the development of PBL research has taken place over the past decade.

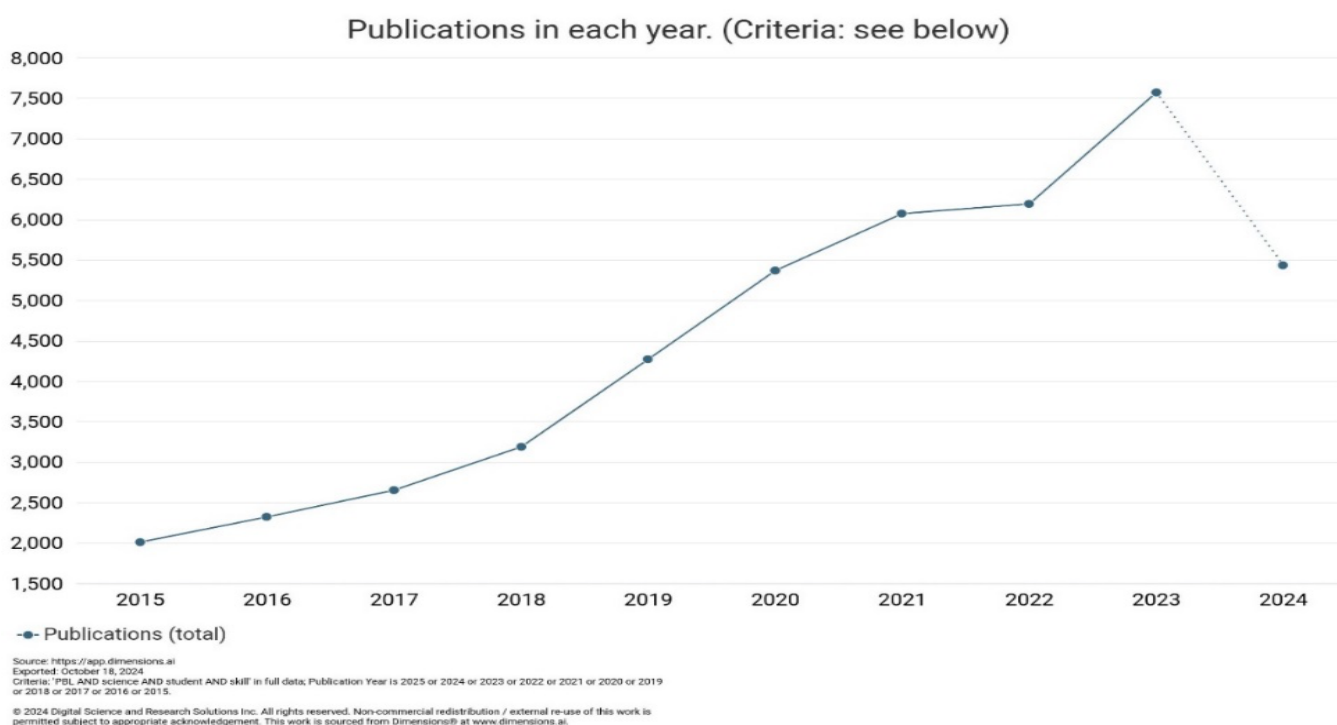


Figure 1. Research trends 2015-2024

First, figure 1 above shows the trend of PBL-related publications from 2015 to 2024. This trend shows a steady increase in the number of publications from 2015 to reaching its peak in 2023. This increase is in line with the growing importance of developing 21st-century skills such as problem-solving and critical thinking, which are taking center stage in modern education (Van Laar et al., 2020). According to Parker et al. (2022), this increasing trend reflects the increasing number of researchers who recognize the effectiveness of PBL in

improving critical thinking and problem-solving skills, especially in the field of science learning. PBL provides a hands-on, experience-based approach, allowing students to learn through real-world problem-solving, which is more relevant to real-world challenges. The decline in 2024 could be due to a shift in research focus or the emergence of new learning models that are also effective in developing these skills. As explained by Kaufman (2013), research trends can fluctuate according to the evolving needs and priorities of education.

Table 1. Publication Type

Publication Type	Number of Publications
Article	27,870
Chapter	7,529
Proceeding	3,955
Edited Book	3,703
Monograph	1,368
Preprint	669

Then Table 1. describes the distribution of publication types related to PBL in the context of science education. Articles dominated with 27,870 documents, followed by book chapters with 7,529 documents, proceedings as many as 3,955, edited books with 3,703 documents, and monographs with 1,368. Preprints, which are usually used as a form of initial publication before peer review, have the least number of documents at 669. The advantage of scientific articles is their ability to disseminate research results quickly and widely, which supports the growth of academic literature. In addition, scientific articles have a better quality when compared to other types of publications. This is because scientific articles generally go through a long review

process and are examined by many reviewers who are in accordance with their fields and expertise. Scientific articles also take a relatively long time to be published. Then, Suseno et al. (2020) stated that scientific articles are often used as the main reference in the development of learning methods such as PBL because they are able to reach many readers through publications in widely indexed journals. The high number of scientific articles compared to other forms of publication shows that research related to PBL is in great demand in the educational community. Scientific articles are usually used as references more often than books or proceedings, which take longer to publish (Zawacki-Richter et al., 2019). Chapter books also have an important place, as they often contain an in-depth study of the specific topics being studied, including the implementation of PBL in a broader context, such as integration with technology and other cross-disciplinary approaches. However, chapter books require relatively many diverse writers, so the process of inviting writers who are in accordance with the author's context can run longer.

Table 2. Top 10 Journals from 2015-2024

Journal Name	Number of publications	Citations	Citation (Mean)
Advances in Social Science, Education and Humanities Research	1,014	1,178	1.16
Journal of Physics Conference Series	732	4,048	5.53
Science Education Research Journal	666	1,450	2.18
BMC Medical Education	384	7,738	20.15
AIP Conference Proceedings	383	594	1.55
Lecture Notes in Computer Science	382	2,005	5.25
Sustainability	322	5,477	17.01
Education Sciences	290	3,317	11.44
Research Square	263	88	0.33
Encyclopedia of the UN Sustainable Development Goals	249	489	1.96

Table 2, displays 10 journals with the highest number of publications related to PBL research. The journal "Advances in Social Science Education and Humanities Research" ranks first with 1,014 publications, while the "Journal of Physics Conference Series" ranks second with 732 publications, and the "Journal of Science Education Research" ranks third with 666 publications. These journals have an important role in disseminating research results related to innovation in learning, especially the application of PBL. More specifically, the journals "Advances in Social Science Education and Humanities Research" and "Journal of Science Education Research" are journals that publish scientific articles on education. The journal "Science Education Research Journal" has contributed a lot to publishing PBL research in Indonesia, reflecting the growing interest of local researchers in this learning model. Hallinger et al. (2019) stated that educational journals are the main platform to discuss new methodologies such as PBL, which aim to improve 21st-century skills, especially critical thinking and problem-

solving. Publications in these journals show how widespread the application of PBL is in various disciplines. It is very important to ensure that scientific articles can be published in journals that have a main focus on education so that they can produce better articles. Interestingly, the articles produced from the conference have relatively many, namely the "Journal of Physics Conference Series" and "AIP Conference Proceedings". This illustrates that many researchers try to present their research to a conference and publish on these conference journal. The "Journal of Physics Conference Series" contains a lot of research on the application of PBL in exact sciences, such as physics, which requires a problem-solving approach to teach complex concepts.

Then, there is a multidisciplinary journal, namely "Sustainability" published by MPDI, ranks seventh in the number of publications on PBL and students' science process skills. This journal not only publishes about education, but also publishes many disciplines related to

sustainability, including in the fields of economics, business, psychology, biology, engineering, and others.

Table 3. Number of Citations by Document

Number of citations	Citation/year	Year	Writer	Heading
1982	220.2	2016	Hiemenz, Paul C.; Rajagopalan, Raj	Principles of Colloid and Surface Chemistry, Revised and Expanded
1342	134.2	2015	O'Flaherty, Jacqueline; Phillips, Craig	The use of flipped classrooms in higher education: A scoping review
1124	562.0	2023	Gilson, Aidan; Safranek, Conrad W; Huang, Thomas; Socrates, Vimig; Chi, Ling; Taylor, Richard Andrew; Chartash, David	How Does ChatGPT Perform on the United States Medical Licensing Examination? The Implications of Large Language Models for Medical Education and Knowledge Assessment
991	330.3	2022	Park, Sang-Min; Kim, Young-Gab	A Metaverse: Taxonomy, Components, Applications, and Open Challenges
853	94.8	2016	Ruth Colvin Clark, Richard E. Mayer (Eds.)	e-Learning and the Science of Instruction
849	106.1	2017	Peter J.G. Teunissen, Oliver Montenbruck (Eds.)	Springer Handbook of Global Navigation Satellite Systems
836	119.4	2018	Michael Z. Hauschild, Ralph K. Rosenbaum, Stig Irving Olsen (Eds.)	Life Cycle Assessment, Theory and Practice
832	138.7	2019	Andrea Cossarizza; Hyun-Dong Chang; Andreas Radbruch; Andreas Acs; Dieter Adam; Sabine Adam-Klages; William; et.al.	Guidelines for the use of flow cytometry and cell sorting in immunological studies (second edition)
782	86.9	2016	Kokotsaki, Dimitra; Menzies, Victoria; Wiggins, Andy	Project-based learning: A review of the literature
759	94.9	2017	Dichev, Christo; Dicheva, Darina	Gamifying education: what is known, what is believed and what remains uncertain: a critical review

Table 3, shows the number of citations based on the most referenced documents in PBL-related research. The number of citations shows the importance of the article to the development of related research. The higher the number of citations, the more researchers refer to the article. In addition, the number of citations can describe the quality of the article. The work of Hiemenz et al. (2016) "Principles of Colloid and Surface Chemistry" has 1,982 citations, which reflects the great influence of this research in the field of science education, especially in the application of PBL to chemistry learning. In addition, O'Flaherty et al. (2015) with "The Use of Flipped Classrooms in Higher Education" obtained 1,342 citations, confirming that active learning models such as flipped classrooms and PBL have been proven effective in improving students' problem-solving skills (Stehle & Peters-Burton, 2019). The high number of citations in this document shows that PBL-related research is not only relevant in one discipline, but also influential in the broader educational context. According to Kaufman (2013), the use of PBL in higher education, including in flipped classrooms, has encouraged students to be more active in learning, which ultimately improves their ability to analyze and solve complex problems.

Table 4. Keyword Trends

Keywords	Occurrences	Relevance
Critical Thinking Skill	104	0.51
technology	56	0.31
Learning Model	48	0.72
engineering	46	0.37
PJBL	46	0.30
STEM	40	0.42
Science Process Skill	37	0.73
curriculum	34	0.72
experience	33	1.03
High School Student	33	0.84

Table 4 summarizes the keywords that most frequently appear in PBL-related research using VOSviewer. The keyword "critical thinking skill" appears 104 times, indicating that the development of critical thinking skills is the main focus in the implementation of PBL. Other keywords that often appear are "technology" (56 times) and "learning model" (48 times), which indicate the importance of integrating technology in the problem-based learning process to support the development of 21st-century skills. The use of technology in PBL allows students to collaborate more effectively and access information more broadly, thus facilitating a better problem-solving process (Van Laar et al., 2020). Technology is dynamic, constantly

undergoing development and renewal according to human needs. It is undeniable that research to create technology-based learning models will continue to develop in the future. Therefore, many researchers pay attention to utilizing technology in the world of education so that it can improve students' abilities and skills (Aslan & Duruhan, 2021; District et al., 2024; Eldy et al., 2023; Ernawati et al., 2023; Fuadi et al., 2021; Wijnia

et al., 2024). In addition, keywords such as "STEM" and "science process skill" indicate that PBL is often associated with an interdisciplinary approach, particularly in the fields of science and technology (Aizman et al., 2017; Alfiana & Yogihati, 2021; Bicer et al., 2019; Guo & Tang, 2021; Pitot et al., 2024; Purnamasari & Utomo, 2020; Ruamcharoen et al., 2021).

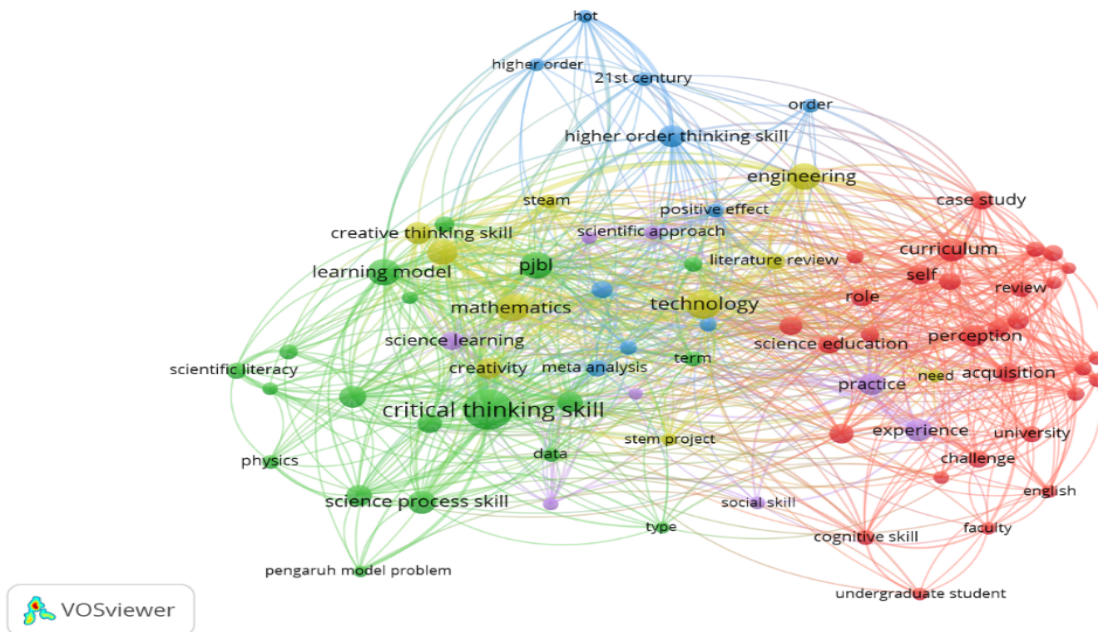


Figure 2. Network visualization

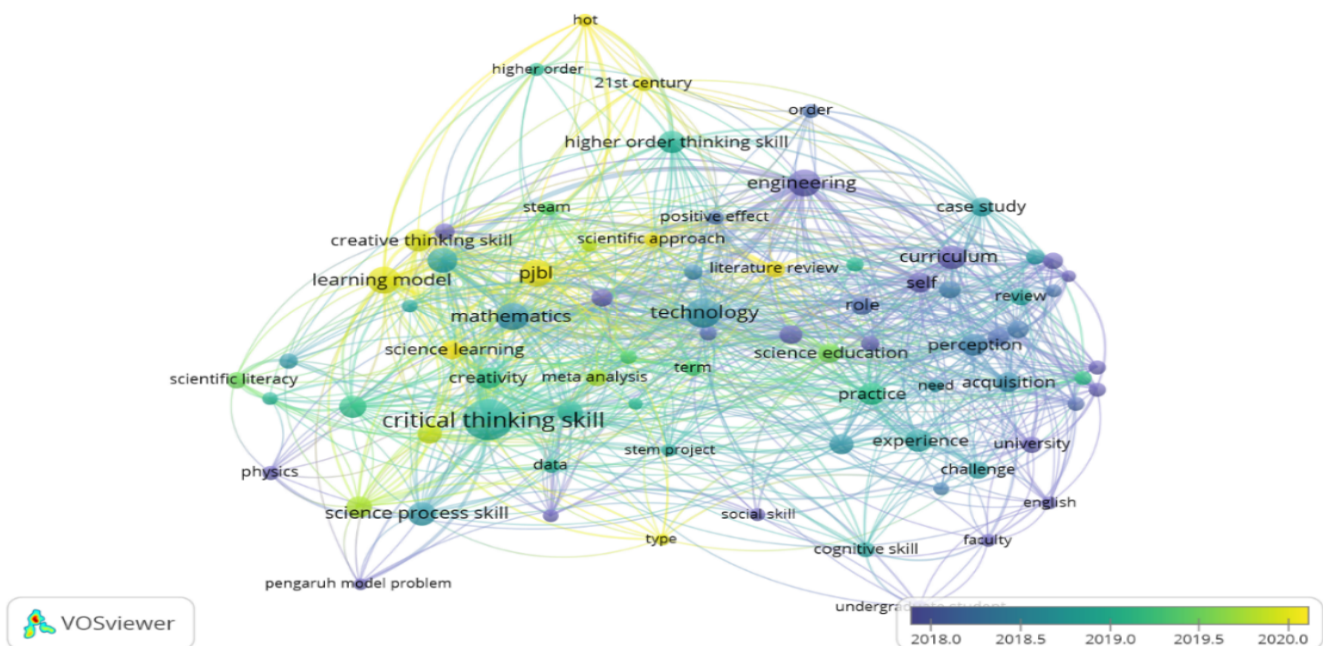


Figure 3. Overly visualization

Then Figure 2, illustrates the network of keywords that often appear in PBL research. This visualization shows a close relationship between concepts such as

"creative thinking," "critical thinking," "STEM," and "technology." This network shows that PBL research does not only focus on one aspect of learning, but also

seeks to integrate various components that can support more holistic learning (Stehle & Peters-Burton, 2019). The integration of PBL with STEM approaches allows students to develop a variety of skills, including critical thinking, problem-solving, and creativity. This is in line with the findings of Hebebcı et al. (2022) which states that the PBL approach is very effective in improving 21st century skills when combined with technology and science.

Figure 3 shows an overlay visualization of the keyword trends used in PBL-related research. These

visualizations illustrate changing trends over time, with keywords such as "technology" and "creative thinking" dominating in 2020. In the following years, attention shifted to "critical thinking" and "STEM," indicating a shift in focus in research more oriented towards the development of critical thinking skills and the integration of technology in learning. According to Parker et al. (2022), this changing trend reflects the ever-evolving need in modern education, where technology is increasingly playing an important role in problem-based learning.

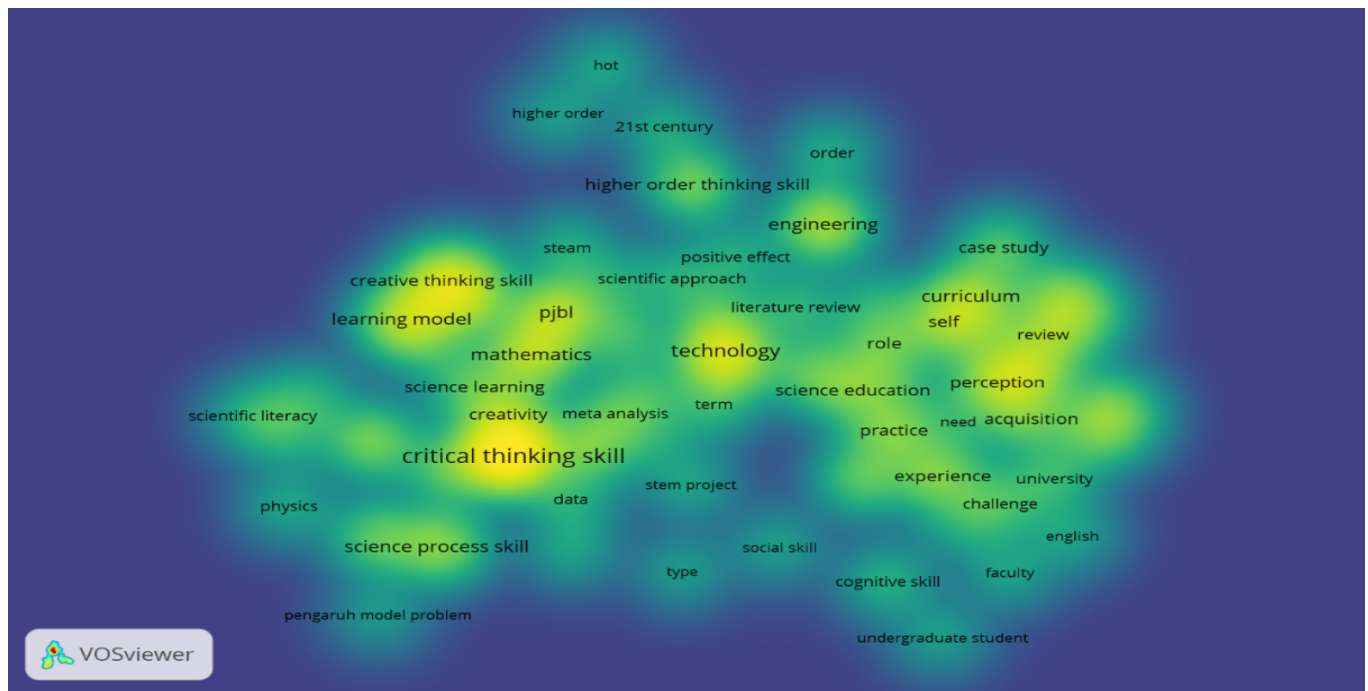


Figure 4. Density visualization

Finally, Figure 4, displays a visualization of keyword density, where lighter areas show the most frequently used keywords in PBL-related research. Keywords such as "science learning," "STEM project," and "critical thinking" stand out in this visualization, suggesting that these topics are gaining a lot of attention in the scientific community. According to Markula & Aksela (2022), density visualization helps identify the most in-demand research areas and shows how the research focus continues to grow, especially related to the use of PBL in the development of problem-solving skills in science education.

Conclusion

Based on the analysis conducted, it can be concluded that the application of PBL in improving problem-solving skills in the field of science learning has continued to increase in the last decade. Research trends show that the integration of PBL with technology and STEM is a major concern for researchers, and scientific articles remain the most dominant form of publication.

Keywords such as "critical thinking" and "technology" frequently appear in the study, reflecting a strong focus on 21st-century skill development. However, although there have been many studies that have discussed the effectiveness of PBL, there are still some areas that have not been widely explored, such as the integration of local wisdom, inquiry methods, and the development of social and communication skills through PBL. Future research could focus more on these topics, given the importance of these skills in an increasingly global and digital educational context. In addition, technology that has a highly dynastic nature and continues to develop in accordance with the needs and challenges of the times makes the development of more effective technology-based learning models still possible in the future. With the ever-evolving technology and the need for 21st-century skills, PBL has great potential to continue to evolve as a learning approach capable of preparing students for real-world challenges. More in-depth research on the use of advanced technologies in PBL, such as artificial intelligence and virtual reality, could

also be the focus of future research to enrich students' learning experiences.

Acknowledgments

Thank you to all parties who have helped in this research so that this article can be published

Author Contributions

All authors contributed to writing this article.

Funding

No external funding.

Conflicts of Interest

No conflict interest.

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