Research Trends of Problem Based Learning (PBL) Based E-Modules to Improve Students' Science Process Skills in Science Learning: Bibliometric Analysis (2015-2024)

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Abstract: Improving science process skills is one of the important focuses in 21st century science education. One effective method is the use of e-modules based on Problem Based Learning (PBL) that can help students develop these skills. This study aims to review research trends related to the use of PBL-based e-modules in improving students' science process skills in the period 2015 to 2024. This research method uses a descriptive and analytical approach with data obtained from scientific publications indexed by Google Scholar, using tools such as Publish or Perish and Dimension.ai. The analysis process is carried out based on PRISMA guidelines to filter and assess the quality of documents. The collected data was analyzed using a bibliometric approach with the help of VOSviewer software to map the main keywords. The results showed that the research trend related to PBL-based e-modules experienced a significant increase from 2015 to 2023, but slightly decreased in 2024. Scientific articles became the most dominant type of publication, indicating a high interest in the use of PBL-based e-modules. Some of the keywords that frequently appear are "problem solving ability," "STEM approach," and "critical thinking skill," indicating the main focus on the development of critical thinking skills and the integration of the STEM approach. This research provides a comprehensive overview of the development of PBL-based e-module research trends in science learning, as well as identifying further development opportunities such as the integration of local wisdom and technology to improve students' science process skills.

Keywords: Bibliometric analysis; E-modules; PBL; Science education; Science process skills

Introduction

Improving the quality of 21st century education requires students to have a variety of relevant skills, one of which is science process skills. These skills include the ability to observe, classify, measure, predict, and make conclusions from scientific phenomena around them. This ability is an important basis for students to understand scientific concepts in depth and apply them in everyday life. In Indonesia, there are still many challenges in developing science process skills, mainly due to learning methods that tend to be conventional and less interactive. Therefore, learning innovations are needed that can stimulate active student involvement in the learning process (Amelia, 2023; Coil et al., 2010; Mabsutsah et al., 2022).

One of these innovations is e-modules based on Problem Based Learning (PBL). PBL-based e-modules are designed to provide interactive and relevant learning experiences with real problems, so that students are more motivated in learning science materials. PBL encourages students to explore and solve problems related to science material, which in turn can improve their science process skills. Various studies have shown that the application of PBL-based e-modules can improve students' conceptual understanding, critical thinking skills, and creativity. However, this research trend has not been

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systematically reviewed to understand its development and potential for further development (Hafizah, 2024; Putra et al., 2023; Rahman, 2022).

This study aims to review research trends related to PBL-based e-modules in improving students' science process skills in science learning from 2015 to 2024. This review is conducted through bibliometric analysis which aims to provide a comprehensive overview of research developments on this topic. Using bibliometric analysis method, this research focuses on identifying the main keywords, publication distribution, and main publication sources relevant in PBL-based e-module research. The results of this study are expected to be a reference for the development of better e-modules and learning innovations in the future, as well as providing insight into the relevance and effectiveness of the PBL approach in improving students' science process skills (Cholily et al., 2024; Fitriyani, 2022; Yesi, 2024).

Method

This study uses a descriptive and analytical approach with bibliometric analysis method to review research trends related to e-modules based on Problem Based Learning (PBL) in improving students' science process skills in science learning. The data used in this study were obtained from scientific publications indexed by Google Scholar. To collect publication data, analysis tools such as Publish or Perish and Dimension.ai are used, which allow researchers to obtain publication data from 2015 to 2024.

The data analysis process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which included the stages of document identification, selection, and quality assessment. In the identification stage, researchers used keywords such as "e-modules," "Problem Based Learning," "science process skills," and "science" to find relevant documents. The selection stage is carried out by removing documents that do not meet the relevance criteria, and evaluating the quality of documents based on the number of citations and content relevance (Arman, 2021; Dwilaga, 2023; Mahwati, 2024).

The filtered data was then analyzed using VOSviewer software to visualize the relationship between the main keywords used in the research. Bibliometric analysis was conducted to map research trends, main themes, and patterns that emerged in research on PBL-based e-modules. In addition, data visualization was conducted in the form of network visualization, overlay visualization, and density visualization to understand the distribution of keywords and identify potential areas for further exploration (Arifin et al., 2023; Rohmah et al., 2024).

Result and Discussion

This analysis aims to reveal research trends related to the use of e-modules based on Problem Based Learning (PBL) in improving students' science process skills in science learning during the period 2015 to 2024. The following presents various main findings that include the development of publication trends, the dominant types of publications, and visualization of keyword networks that often appear in research.

Trends in Research Publications

Figure 1 shows the publication trend regarding PBL-based e-modules to improve students' science process skills from 2015 to 2024. Based on the data in Figure 1, there is a significant increase in the number of publications from 2015 to 2023, with the peak number of publications occurring in 2023 which reached more than 700 publications. At the beginning of the period (2015-2017), the number of publications was still relatively low, with less than 100 publications per year. However, starting in 2018, this trend experienced a consistent increase along with increasing awareness of the importance of science process skills and the use of PBL in science learning.
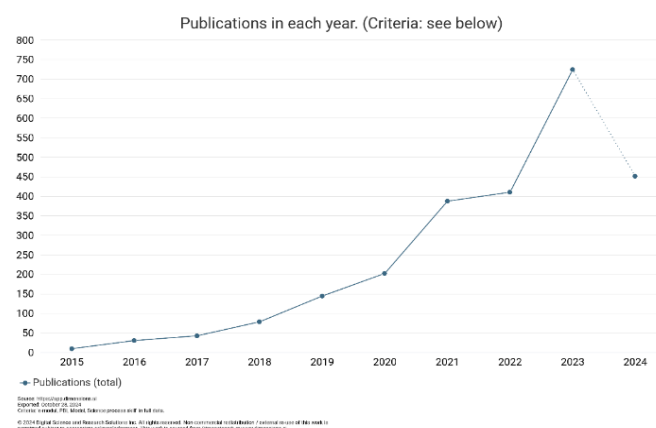

Figure 1. Research trends of PBL-based e-modules for improving science process skills (2015–2024)

The significant increase in 2020 can be attributed to the increasing use of e-modules as a learning solution in the COVID-19 pandemic era, which encourages the application of more independent and interactive learning methods. In addition, support from national and international education policies for the use of technology in learning also plays a role in increasing the number of publications (Desrarani, 2024; Indriati et al., 2023; Ismawati et al., 2021; Karnando et al., 2021).

The decrease in the number of publications in 2024 may be due to several factors, such as a change in research focus to more specific topics or a shift in education policy. However, the overall trend shows a

steady increase from 2015 to 2023, reflecting the great interest and attention from the academic community towards the development of PBL-based e-modules in science education (Dikananda et al., 2024; Husna et al., 2024).

Overall, this data indicates that research related to PBL-based e-modules has continued to grow in recent years, with the main focus on developing students' science process skills. The dominance of publications in recent years indicates that this topic is increasingly relevant to the needs of 21st century education, especially in developing critical thinking skills, problem solving, and mastery of scientific concepts.

Publication Type

The increasing number of publications on PBL-based e-modules over the period 2015 to 2023 shows the growing interest of academics in this topic. This increasing trend is also seen in the variety of publication types used to disseminate research findings. The variety of publication forms provides a broader picture of how research related to PBL-based e-modules is presented in scientific circles.

Table 1. Trends in PBL-based E-modules for Improving Science Process Skills Based on Publication Type (2015-2024)

Publication Type	Publications
Article	2,020
Edited Book	283
Proceeding	187
Chapter	113
Monograph	31
Preprint	1

Table 1 shows the distribution of publication types used in research related to PBL-based e-modules to improve science process skills. Scientific articles are the most dominant form of publication with a total of 2,020 publications, followed by edited books with 283 publications, and proceedings with 187 publications. Other forms of publication such as book chapters, monographs, and preprints recorded 113, 31, and 1 publications respectively.

The dominance of scientific articles indicates that the topic of PBL-based e-modules is more often published in the form of journals, which allows researchers to present their research results in an in-depth and structured manner. On the other hand, the significant number of proceedings shows that conferences are also an important platform for academics to share research findings related to this topic. Although the number of monographs and preprints is relatively small, this indicates a variety in the dissemination of research results, which includes

exploratory studies and the presentation of comprehensive reviews (Kafi, 2023; Priyanto, 2012).

Overall, this distribution of publication types reflects that the topic of PBL-based e-modules to improve science process skills has become a major concern among academics, whether through journal articles, edited books, or conference proceedings. This variation in publication types also indicates that research on this topic is growing and its importance is recognized in various scientific forums.

Primary Sources of Publication

The results of publication type distribution provide an overview of how research related to PBL-based e-modules is disseminated through various platforms. To gain deeper insights, it is important to understand the main sources where this research is frequently published, as well as its contribution and impact in developing related topics (Hartanto et al., 2023; Nartin et al., 2024; Pugu et al., 2024).

Table 2. Ten Main Sources of PBL-Based E-Module Trends for Improving Science Process Skills (2015-2024)

Rank	Journal Name	Publications	Citations
1	Jurnal Penelitian Pendidikan IPA	227	501
2	Advances in Social Science, Education and Humanities Research	129	212
3	Journal of Physics Conference Series	72	570
4	AIP Conference Proceedings	44	15
5	Jurnal Pendidikan Sains Indonesia	34	155
6	Journal of Education Technology	33	187
7	Jurnal Basicedu	28	231
8	JPI (Jurnal Pendidikan Indonesia)	26	116
9	Jurnal Ilmiah Sekolah Dasar	23	96
10	Indonesian Journal of Science and Mathematics Education	23	65

Table 2 shows the ten main sources of research publications on PBL-based e-modules to improve science process skills from 2015 to 2024. The Journal of Science Education Research is the main source with the highest number of publications, namely 227 publications, and a total of 501 citations. This journal is the dominant media in disseminating research related to PBL-based e-modules.

In second place, Advances in Social Science, Education and Humanities Research recorded 129

publications with a total of 212 citations, followed by the Journal of Physics Conference Series which has a smaller number of publications, namely 72 publications. Other journals such as Jurnal Pendidikan Sains Indonesia, Journal of Education Technology, and Jurnal Basicedu also occupy an important position with varying numbers of publications, but with citation rates that indicate their respective contributions in disseminating research related to this topic.

Overall, these key publication sources reflect the diversity and relevance of the topic of PBL-based e-modules in improving students' science process skills. The dominance of several journals in this list also indicates that publications on this topic are not only

widely disseminated, but also gain significant recognition from the academic community through the level of citations obtained.

Key Citations

In addition to understanding the main sources of publications related to PBL-based e-modules, it is important to take a deeper look at the articles that have significant influence in this research. Analysis of key citations helps to identify the works that form the foundation of PBL-based e-modules research and their important contribution in improving students' science process skills (Leonardy, 2023).

Table 3. Ten Key Citations of PBL-Based E-Module Trends for Improving Science Process Skills (2015-2024)

Cites/year	Year	Author	Title
1.00	2024	BNS Zainuri, G Gunawan	Local Wisdom Integration in Problem-Based Learning E-Modules: Impact on Science Literacy and Science Process Skills
56.17	2018	V Serevina, I Astra, IJ Sari	Development of E-Module Based on Problem Based Learning (PBL) on Heat and Temperature to Improve Student's Science Process Skill.
5.00	2024	A Hamidi, R Akmala, I Wilujeng	Development of PBL Based E-Modules to Boost Students' Science Process Skills
6.50	2022	RC Katauhi, W Widodo, DAP Sari	Implementation of the science e-module based on guided inquiry with the flipped classroom strategy to improve students science process skills
1.00	2023	EN Juliana, Z Zainuddin, D Dewantara	Electronic Module with Scientific Approach in Training Students' Science Process Skills on Solid Elasticity Learning Material
2.00	2024	BH Siswati, J Prihatin	Module STEM Biotechnology to Empower Metacognitive Skills and Science Process Skills of High School Students with Low Academic Ability in Industrial Agriculture
21.00	2023	A Ekasari, M Maulidinah	Application of E-Module to Identify Students' Science Process Skills in the Practicum of Refraction on Prisms
2.67	2021	A Fahlevi	Practicality E-Module Of Vibration In Everyday Life On Online Learning To Improve Science Process Skills Of Grade X High School Students
10.00	2023	R Rinjani, DD Romadona	A Study of Student Science Process Skills: In Formal Change Practices
3.00	2022	S Afrianti, N Novita, FW Ginting	Development of STEM-Based LKPD with Guided Inquiry Design to Improve Student's Science Process Skills

Table 3 presents the ten most cited articles in research on PBL-based e-modules to improve students' science process skills from 2015 to 2024. The article written by Serevina, Astra, and Sari in 2018 recorded the highest average citations per year, 56.17 citations, with the title "Development of E-Module Based on Problem Based Learning (PBL) on Heat and Temperature to Improve Student's Science Process Skill". This article became one of the main works that contributed to the development of PBL-based e-modules with a focus on the topic of heat and temperature.

Other notable works include articles from Maulidinah et al. (2023) with an average of 21 citations per year, which discussed the application of e-modules

in identifying students' science process skills in the practicum of refraction in prisms. This article indicates that research on PBL-based e-modules not only focuses on the development of scientific concepts, but also their application in practical situations to hone science process skills.

In addition, articles written by Katauhi et al. (2022) recorded an average of 6.50 citations per year with the title "Implementation of the science e-module based on guided inquiry with the flipped classroom strategy to improve students science process skills." This shows that the inquiry approach integrated with PBL in the form of e-modules is one method that is widely recognized as effective for improving student skills.

Overall, this list of key citations provides an insight into the influential works that form the foundation for research into PBL-based e-modules. The large number of citations received by some key articles demonstrates the recognition and relevance of this topic within the academic community, as well as providing an overview of the main focus and innovations applied in this research.

Key Research Topics

The identification of key articles that made a major contribution to the PBL-based e-module research was followed by an analysis of keyword usage trends in this research. This analysis aims to provide a more detailed picture of the main themes that are often reviewed and important concepts that are the focus of the research.

Table 4 displays the keywords that are often used in research related to PBL-based e-modules to improve students' science process skills in the period 2015 to 2024. The keyword "STEM approach" has the highest frequency, appearing 6 times, with a relevance level of 1.19. This shows that there is great attention to the STEM approach (Science, Technology, Engineering, Mathematics) in the context of developing PBL-based e-modules.

In addition, keywords such as "research method" and "communication skill" appeared 5 times, indicating that this research also focuses on research methods and the development of students' communication skills. Other frequently occurring keywords, such as "problem solving ability" and "students creative thinking skill," indicate that the PBL-based e-module research focuses on developing students' problem solving ability and creative thinking, which are essential skills in science learning.

The presence of the keywords "cognitive learning outcome" and "higher order thinking skill" indicates a special attention to the improvement of cognitive learning outcomes and higher order thinking skills through the application of PBL-based e-modules. In addition, the keyword "science subject" emphasizes that this research generally focuses on the application of e-modules in science subjects.

Overall, this keyword analysis provides an overview of the important elements that are the focus in the development and implementation of PBL-based e-modules. The use of keywords such as "STEM approach," "problem solving ability," and "communication skill" shows that this research focuses not only on understanding science concepts, but also on developing students' critical thinking, problem solving, and communication skills.

Table 4. Keywords on PBL-based e-module trends to improve science process skills (2015-2024)

Terms	Occurrences	Relevance
Based e-module	3	2.61
Problem solving ability	4	2.47
Students creative thinking skill	4	1.70
Research method	5	1.54
Advantage	4	1.39
Communication skill	5	1.31
Higher order thinking skill	3	1.25
Cognitive learning outcome	4	1.22
STEM approach	6	1.19
Science subject	4	1.15

Temporal Evolution of Research Topics

The keyword analysis that has been conducted provides insight into the main themes that are often the focus of research related to PBL-based e-modules. To understand the relationship between concepts and their interrelationships, network visualization was used to map the keywords that frequently appear and their relationship with each other.

Figure 2 shows the visualization of the keyword network in the PBL-based e-module research to improve students' science process skills. This visualization illustrates the relationship between keywords based on their frequency of occurrence and the relationship between the main concepts that are often discussed. In this visualization, it can be seen that the keyword "process skill" is at the center of the network, indicating that the topic of science process skills is the main focus in this research.

Other keywords such as "PjBL," "e-module based," and "STEM approach" also have strong connections, reflecting the linkage between the project-based learning model with the development of problem-based modules and the STEM approach. In addition, concepts such as "communication skill," "inquiry," and "creative thinking skill" also appear to be closely connected, indicating that this research focuses not only on scientific skills, but also on developing students' critical thinking and communication skills.

This figure shows that there are several clusters that indicate well-organized research themes. For example, clusters that include keywords such as "scientific process," "scientific method," and "technology" indicate a focus on developing students' scientific skills through technology integration. Other clusters such as "local wisdom" and "ethnoscience" indicate research exploring the integration of local wisdom in project-based teaching.

This visualization provides a comprehensive overview of PBL-based e-module research trends, with an emphasis on the importance of science process skills as the main focus. In addition, this visualization also shows the integration of various other important

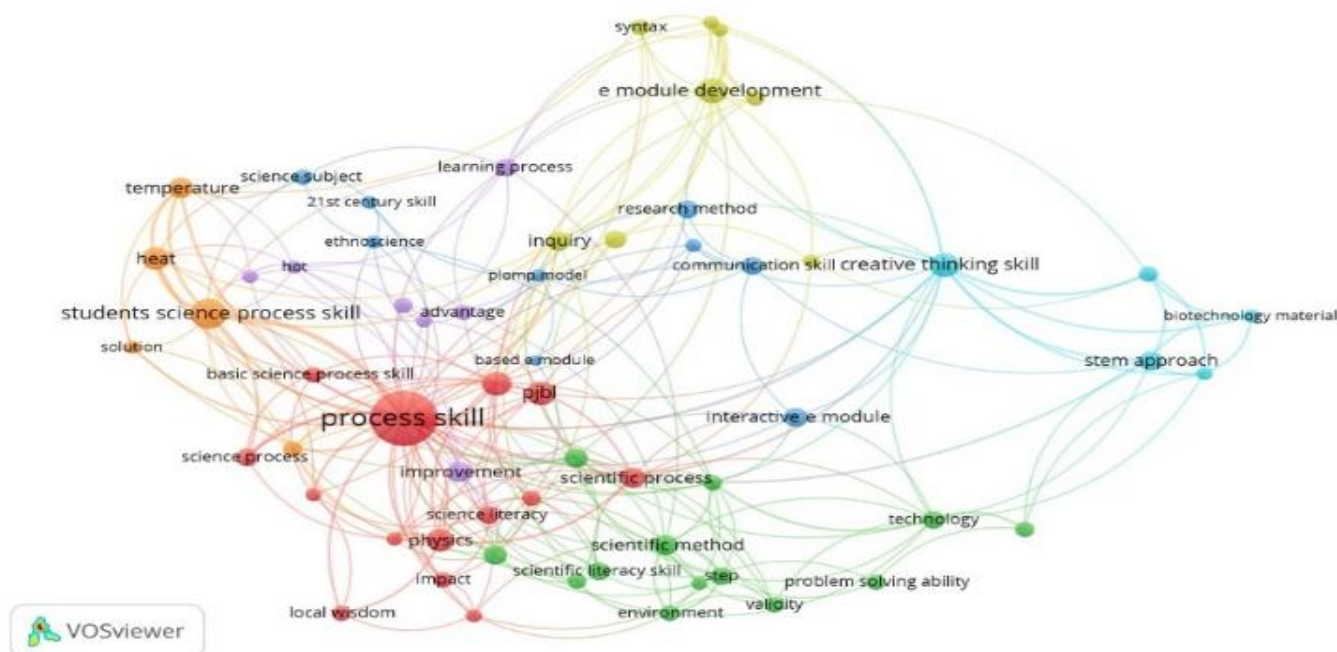concepts, such as STEM approaches, technology, and creativity, in the development of PBL-based e-modules.

Figure 2. Network visualization on research trends e-modules based on problem based learning (PBL) to improve students' science process skills in science learning

Overlays on Research Trends

Understanding the relationships between keywords through network visualization demonstrates the need to see how these research trends evolve over time. The overlay visualization provides additional information on the timing of keyword occurrence, which is useful in identifying the development of key topics across different periods.
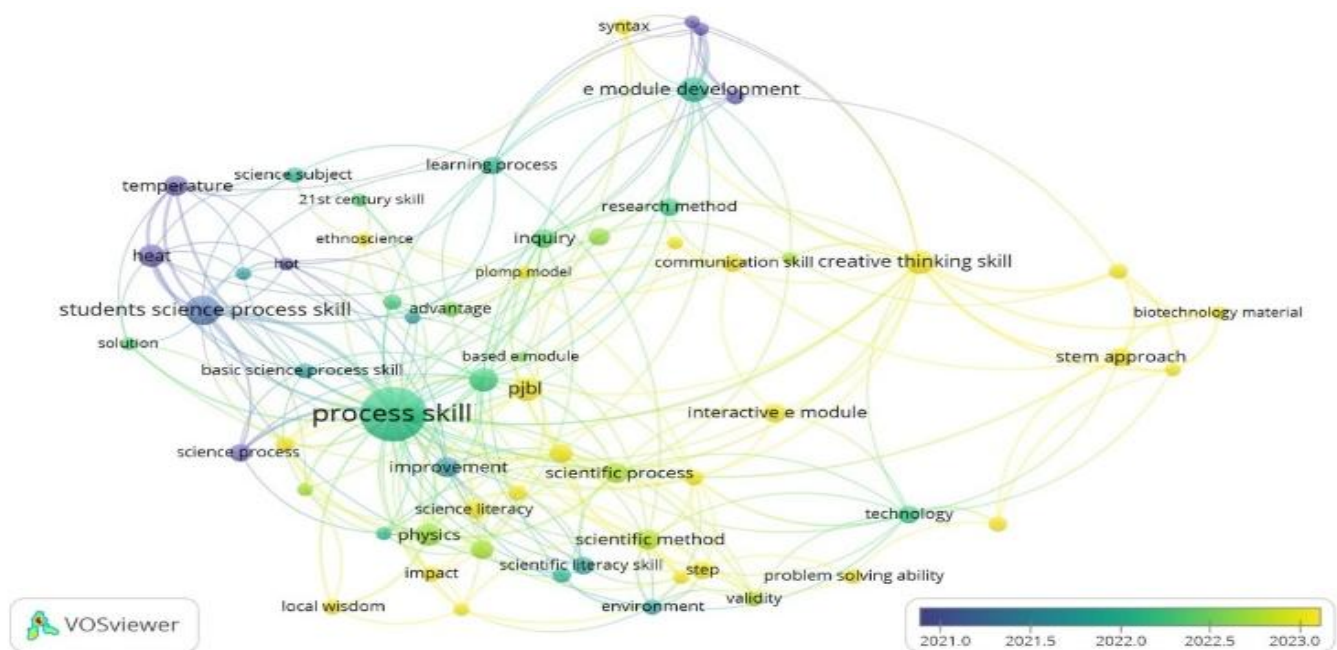

Figure 3. Visualization of overlays on research trends e-modules based on problem based learning (PBL) to improve students' science process skills in science learning

Figure 3 shows an overlay visualization on the research trends of PBL-based e-modules to improve students' science process skills in science learning. In this visualization, lighter colors, such as yellow, indicate

keywords that frequently appear in the latest research (2022-2023), while darker colors indicate keywords that are dominant in the previous period.

Keywords such as "e module development" and "stem approach" appear in bright yellow, indicating that these topics are the main focus of recent research. This suggests that the development of PBL-based e-modules is increasingly leading to the integration of STEM approaches and innovation in module development. On the other hand, keywords such as "process skill" and "students science process skill" consistently appear in various periods, indicating that the improvement of science process skills is still a major concern throughout the research time span.

The presence of keywords such as "creative thinking skills" and "communication skills" in lighter colors indicates a stronger focus on developing 21st century skills, which include creative thinking and communication. In addition, topics related to local wisdom such as "local wisdom" have also begun to receive more attention in recent years, signaling an effort to integrate cultural context in the PBL approach.

Through this overlay visualization, it can be seen that the research trend of PBL-based e-modules has not only developed in terms of themes and approaches, but also in the integration of various concepts and contexts that are relevant to today's educational needs.

Thematic Clusters

The overlay visualization provides information on how keyword trends evolve in PBL-based e-module research from year to year. To complement this analysis, the density visualization can provide an overview of the frequency of keyword occurrence, helping to identify the most frequently researched and relevant topics within these trends.
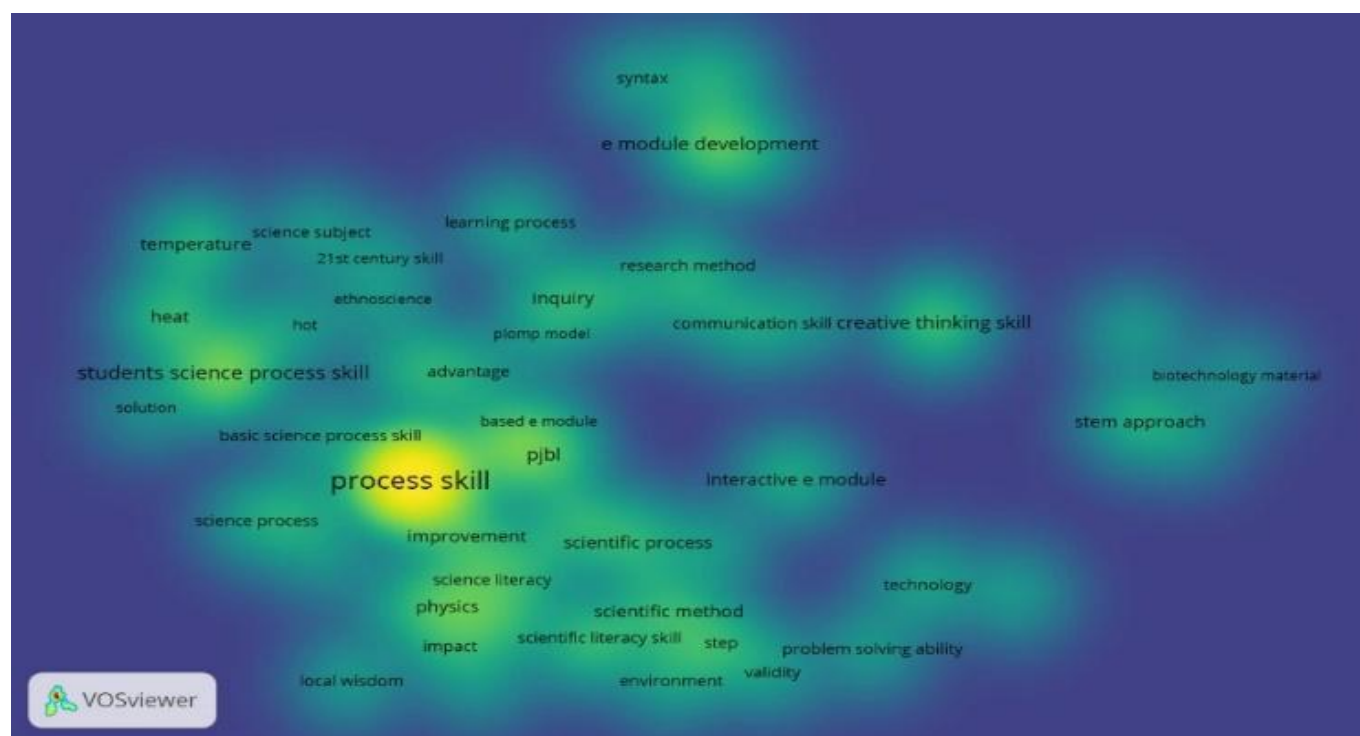

Figure 4. Visualization of density on research trends e-modules based on problem based learning (PBL) to improve students' science process skills in science learning

Figure 4 displays the density visualization on the research trend of PBL-based e-modules to improve students' science process skills. This visualization shows the density of keyword occurrences in various research areas. The bright yellow color indicates areas with high frequency of keyword occurrence, while green to blue colors indicate areas with lower occurrence.

The keyword "process skills" stands out in bright yellow, indicating a consistent focus on the development of science process skills as a key theme in this study. Keywords such as "PjBL," "e module development," and "STEM approach" also have high density, signaling the importance of these approaches in module development and the application of problem-based learning strategies.

In addition, several keywords such as "communication skill," "creative thinking skill," and "scientific literacy" also appear with a fairly bright density. This indicates that the development of communication skills, creativity, and scientific literacy also received significant attention in the PBL-based e-module research. Meanwhile, the keywords "local

wisdom" and "ethnoscience" appear with lower density, but still show a relevant trend towards the integration of local wisdom in this learning approach.

Through this density visualization, it can be concluded that research related to PBL-based e-modules continues to grow with the main focus on improving science process skills and the integration of other important concepts, such as STEM and 21st century skills.

Conclusion

This study reveals a significant trend in the use of e-modules based on Problem Based Learning (PBL) to improve students' science process skills in science learning during the period 2015 to 2024. Based on the results of the analysis, there is a consistent increase in the number of publications until it reaches its peak in 2023. The distribution of publication types shows the dominance of scientific articles as the main platform for disseminating research findings, signaling the relevance and recognition of this topic in the academic community. Key publication sources such as the Journal of Science Education Research and the Journal of Physics Conference Series are important media with a high number of publications and citation rates. Key citations from several key studies also indicate that this topic is widely studied and recognized for its impact on improving students' science process skills. Important themes that frequently emerge in this research include the development of critical thinking, communication and creativity skills, all of which are becoming essential skills in the 21st century. Network visualizations and overlays identified linkages between the various keywords used, highlighting the importance of integrating STEM approaches and problem-based module development. This trend also leads to an additional focus on developing ethnoscience and local wisdom concepts in project-based learning. The density visualization reinforces these findings by showing a high density of keyword occurrences for key themes such as "process skills," "STEM approach," and "e module development," indicating a consistent focus on developing science process skills. This research provides deep insights into the development and research trends of PBL-based e-modules in science learning. This trend shows great potential in integrating various approaches to develop students' skills, which include scientific skills, critical thinking, communication, and creativity. The development of PBL-based e-modules also provides a new direction in learning approaches that are innovative and relevant to the demands of 21st century education.

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