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Research Mapping of E-Module Integration with Problem Based Learning Model in Physics Learning: A Bibliometric Analysis

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ABSTRACT

Twenty first century education emphasizes the development of critical thinking, creativity, collaboration, communication, and problem-solving skills through the use of digital technology and innovative learning models. This study aims to map and analyze the effectiveness of integrating the Problem-Based Learning (PBL) model into e-modules to improve students' problem-solving skills in physics learning. This study employed bibliometric analysis by reviewing literature published between 2017 and 2025, using VOSviewer software for data visualization and analysis. The documents analyzed were articles indexed in the Scopus database, selected based on their relevance to the development, implementation, or integration of e-modules in physics education that use or are related to the Problem-Based Learning (PBL) model. These findings reveal that research on PBL integration in e-module development is still relatively new, but shows promising potential for innovation in physics learning. Network and density visualizations indicate that this topic is continuously evolving and aligned with current educational demands. Recent trends indicate that integrating PBL into e-modules can significantly improve students' problem-solving skills while addressing low academic achievement. Therefore, this study highlights the importance of implementing innovative learning models as a strategic effort to improve the quality of learning and educational outcomes in the 21st century.

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INTRODUCTION

Learning in the digital era demands a transformation in educational practices to produce graduates prepared to face the complexities of the modern world. Global curricula increasingly emphasize the importance of 21st-century skills, also known as the 4Cs: critical thinking, creativity, collaboration, and communication, as key elements for success. Integrating these skills is essential in all subjects, including science and physics. Because physics is closely related to natural phenomena, these subjects have great potential to foster higher-order reasoning skills and conceptual application. Unfortunately, traditional teaching methods, which tend to be teacher-centered and require memorization of formulas, often hinder this potential. Therefore, pedagogical innovations oriented toward developing application skills and deep thinking are urgently needed. The 21st century has presented new challenges in the world of education, where the focus of learning is not only on mastering concepts, but also on developing skills such as critical thinking, creativity, collaboration, communication, and problem solving (Humam et al., 2025; Humam et al., 2025; Salsabilla et al., 2025; Wahyuni et al., 2025; Andriyani & Nuroh, 2025). In the context of physics learning, students' problem-solving skills are often a primary concern. Many students still struggle to understand and connect physics concepts to real-life situations. As a result, they are unable to apply these concepts in authentic and complex situations (Yuliani et al., 2025; Magfirah, 2024). One learning approach that addresses these challenges is the problem-based learning (PBL) model. PBL places students in real-world situations or simulated problems, which they then analyze, discuss, and solve cooperatively, making learning more active, reflective, and meaningful (Roni Abdani &Joni Rokhmat, 2018; Aziza et al., 2025). One learning approach that addresses these challenges is the problem-based learning (PBL) model. PBL places students in real-world situations or simulated problems, which they then analyze, discuss, and solve cooperatively, making learning more active, reflective, and meaningful (Roni Abdani &Joni Rokhmat, 2018; Aziza et al., 2025). Meanwhile, developments in digital technology have enabled the transformation of conventional learning media into flexible, interactive, and easily accessible electronic modules (e-modules). The use of e-modules in physics learning has been shown to support problem-solving skills, conceptual understanding, and scientific literacy (M. Wulandari, 2023). The use of e-modules in physics learning has been shown to support problem-solving skills, conceptual understanding, and scientific literacy (M. Wulandari, 2023).

The integration of e-modules and the Problem-Based Learning (PBL) model offers a highly promising innovation in physics education. This combination is effective because it combines the flexibility and interactivity of digital media with a learning framework focused on real-world problems. PBL is inherently designed to foster 21st-century skills such as critical thinking and problem-solving. Therefore, the synergistic application of these two elements has the potential to significantly improve the effectiveness and quality of student learning outcomes. For example, a study by Effectiveness of Learning With PBL Model Based on E Modules to Improve Critical Thinking Skills showed that PBL-based e-modules on the concept of static fluids successfully improved students' critical thinking skills with an average N-Gain of 0.512 compared to the control group (Novianti et al., 2025). In addition, research by Integration of PBL Based E-Modules in Physics Education: Improving Problem Solving Skills on Static Fluid Concept showed an increase in the average score from 47.91 to 73.11 after the implementation of PBL-based e-modules in the topic of static fluids (the practical effect is very large) (Yuliani et al., 2025).

Despite the significant synergistic potential between e-modules and Problem-Based Learning (PBL) models, literature specifically mapping research on their integration in physics learning remains limited. This limitation is evident in the lack of in-depth analysis of research trends, emerging keywords, and existing collaborative networks. A systematic review study by Analysis of the Use of E-Modules to Support Students' Abilities in Learning Physics in High Schools: Systematic Literature Review has confirmed that e-modules effectively support student abilities such as problem-solving, higher-order thinking, and creativity. However, the review has not specifically examined how this effectiveness is optimized through integration with a PBL framework. Therefore, there is a significant gap in the literature that needs to be filled with more detailed mapping. Further research is needed to uncover the full potential of this innovative combination (M. Wulandari, 2023).

Based on the background presented, this scientific article has the primary objective of conducting an in-depth bibliometric analysis of studies discussing the integration of e-modules and Problem-Based Learning (PBL) models in the context of physics learning. This analysis will limit the publication period to 2017 to 2025 to ensure the data's relevance to current developments. The bibliometric approach was chosen because it allows for a quantitative and systematic literature review. This will provide an objective overview of the status and direction of research in this specific topic. Thus, this study aims to fill the existing literature gap.

The primary focus of this bibliometric analysis is to identify year-over-year publication trends, which can indicate research interest and growth in this field. Furthermore, this research will map the network of the most frequently occurring keywords, which serve as indicators of dominant specific topics. The mapping will also include the formation of research clusters, or groups of studies with closely related themes. Furthermore, we will identify potential areas for further development in this field based on the data patterns discovered. All of this mapping is essential to providing structured and comprehensive insights.

The systematic mapping results presented in this article are expected to make significant contributions to academia and educational practice. The research trends and cluster data will serve as valuable guidance for researchers in identifying underexplored areas and formulating future research agendas. Furthermore, these findings directly contribute to the development of more innovative and effective physics learning practices. Ultimately, this mapping aims to help educators integrate technology and learning models relevant to the needs of 21st-century skills. Therefore, this research has high practical value.

METHODS

This research employed a bibliometric analysis method. This method employs a quantitative approach to describe, evaluate, and monitor published research results, ensuring more objective and transparent results while minimizing biases commonly found in qualitative methods (Mari, 2019). This approach is quantitative and systematic, allowing for an objective analysis of relevant literature. Through this method, collaboration patterns, keyword distribution, and the dynamics of scientific publications on the research topic can be identified.

The data in this study were obtained from the Scopus database. Scopus was chosen as the primary data source due to its extensive coverage of globally reputable scientific journals. The search was conducted by selecting articles published between 2017 and 2025. The data were limited to specific document types, including journal articles, conference papers, conference reviews, and review articles. A systematic selection process was carried out to ensure the relevance to the research topic and the quality of the data analyzed.

Keywords were carefully selected to ensure that the retrieved literature was relevant to the research topic. The keywords used in the search process included a combination of terms such as "E-module" AND "Problem Based Learning". The search was conducted using boolean operators AND to broaden or narrow the scope of results as needed. The selection of keywords was carried out strategically to ensure that the collected articles reflected the connection reality between physic module and problem based learning.

This study follows systematic steps to ensure clarity in the analytical process. The research procedure was carried out through five stages as proposed (Irawan & Fernando, 2025). The process began with data collection from the Scopus database, followed by article selection based on inclusion criteria, data processing, bibliometric analysis, result visualization, and insight interpretation. Each stage was designed to ensure valid outcomes aligned with the research focus. This process guarantees that only relevant articles meeting scientific criteria were analyzed. The research framework is presented in the form of a diagram to facilitate a clearer understanding of the workflow throughvisual representation.

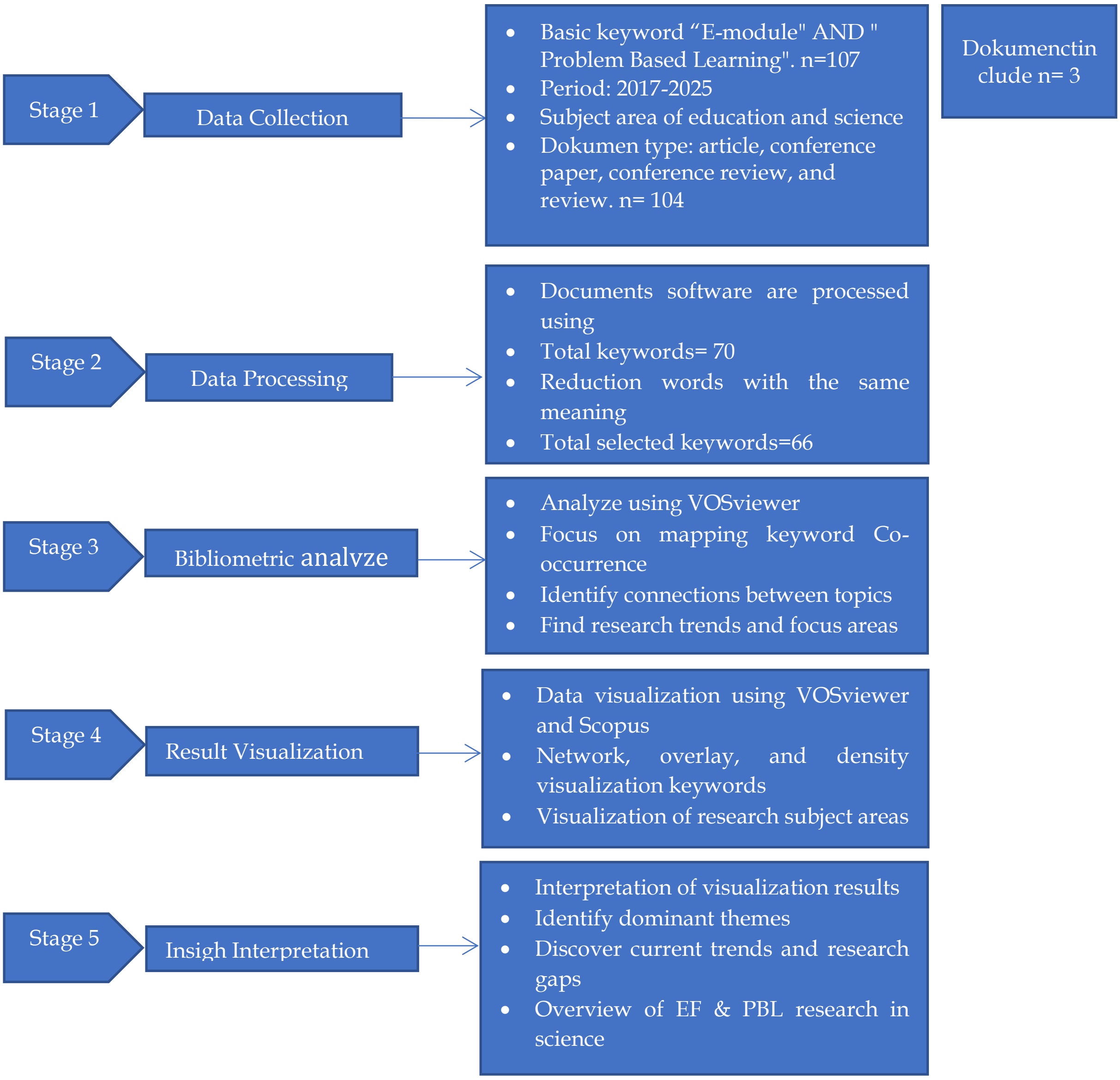

Figure 1. Steps in Bibliometric Analysis Research

Figure 1, this study utilized several software tools to ensure accurate and valid data visualization. The data processing was conducted using Microsoft Excel and Notepad. This stage included a keyword reduction process, which involved merging keywords with similar meanings but different variations in spelling. The visualization and interpretation of the processed data were carried out using VOSviewer. This software was selected due to its ability to produce interactive and easily interpretable visualizations. The outputs generated by VOSviewer served as the basis for interpreting trends and patterns within the analyzed literature data.

Data analysis was carried out by processing metadata obtained from Scopus. The data were then imported into VOSviewer for analysis based on keyword occurrences and relationships among documents. The results were visualized in the form of network visualization, overlay visualization, and density visualization to facilitate the identification of thematic clusters and dominant research trends. Interpretation was conducted descriptively to explain the visual findings. The visualized results such as research development and subject areas were derived from the data analysis conducted using Scopus.

RESULTS AND DISCUSSION

The first result of this study is the analysis of research trends over the past ten years. The data visualization was generated from a Scopus analysis using the keywords "Physich E-module" and "Problem based learning." This graph provides an overview of the dynamics of research growth from year to year. The pattern also reflects the influence of technological advancements, global education policies, and sustainability issues that have gained attention over the past decade.

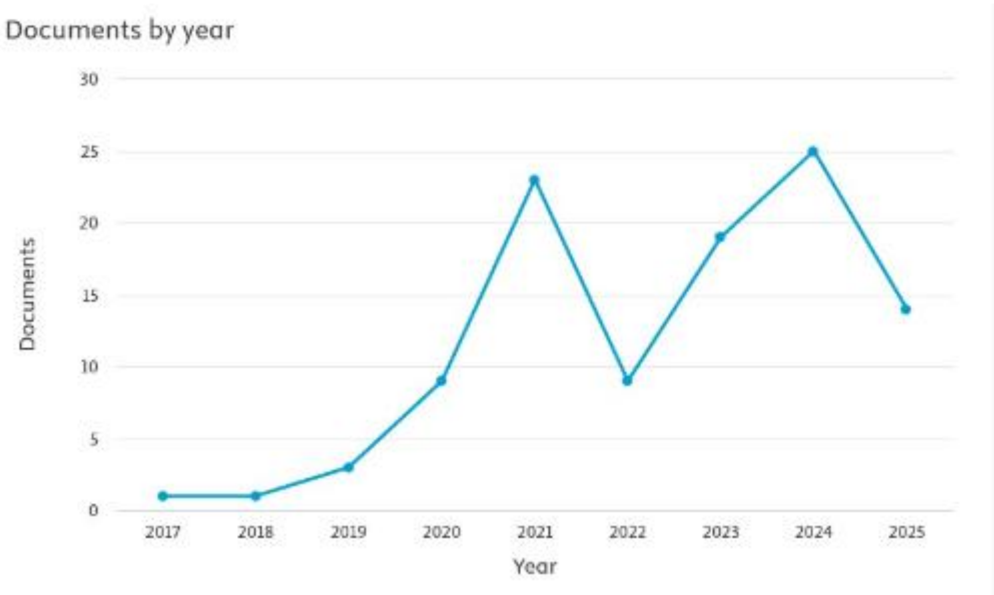

Figure 2. Distribution of Publication Growth from 2017-2025

Figure 2, based on the results of bibliometric analysis in the study entitled "Research Mapping of E-Module Integration with Problem-Based Learning Model in Physics Learning: A Bibliometric Analysis", a significant increasing trend in the number of publications was obtained from 2017 to 2024. In the initial period, namely 2017 to 2018, the number of publications was still very low with only one document identified. The increase began to be seen in 2019 with three documents, indicating the growing interest of researchers in the integration of e-modules in problem-based learning models (Problem Based Learning) in physics learning (Safitri, 2025). This trend continued to increase in 2020 with nine documents indicating an expansion of studies related to digital innovation in science learning (Arifin & Habibi, 2024). The first peak occurred in 2021 with 23 documents, likely influenced by the increasing demand for digital-based learning during the COVID-19 pandemic (Akmala, 2025). Although the number of publications decreased to nine documents in 2022, the research trend increased again in 2023 with 18 documents and reached a second peak in 2024 with 25 documents. This indicates that research on the integration of PBL-based e-modules in physics learning is growing, both in terms of media development, improving critical thinking skills, and student learning motivation (Hafni & Fakhruddin, 2025) . Overall, these results indicate that the topic continues to receive increasing attention from researchers, in line with the need for digital innovation and strengthening scientific literacy in the modern era.

This phenomenon can be explained through Rogers' (2003) diffusion of innovation theory, which states that the adoption of an innovation in education occurs gradually, reaching a peak when the majority of researchers begin using it. Furthermore, Piaget and Vygotsky's constructivist theory also supports this trend, where physics learning is seen as more effective when students actively construct their knowledge through collaboration and problem-solving. The increase in publications also aligns with scientific literacy theory (Bybee, 1997; OECD, 2019), which emphasizes the importance of students' ability to understand and apply scientific concepts in real-life contexts. Thus, the graph reflects the dynamic development of physics research, which continues to adapt to the needs of the times and the demands of developing 21st-century competencies.

Based on this theoretical perspective, it is important to examine how research developments in e-modules and Problem-Based Learning (PBL) contribute to education for sustainable development (ESD) more broadly. The integration of PBL principles into e-modules reflects a growing shift toward learner-centered and technology-based pedagogies that encourage critical thinking and real-world problem-solving. Through network visualization, the interrelationships between authors, keywords, and thematic areas can be analyzed to reveal the structure and evolution of research trends in this domain. This analysis provides valuable insights into how innovative learning models and digital resources are being leveraged to support sustainable and future-oriented education.

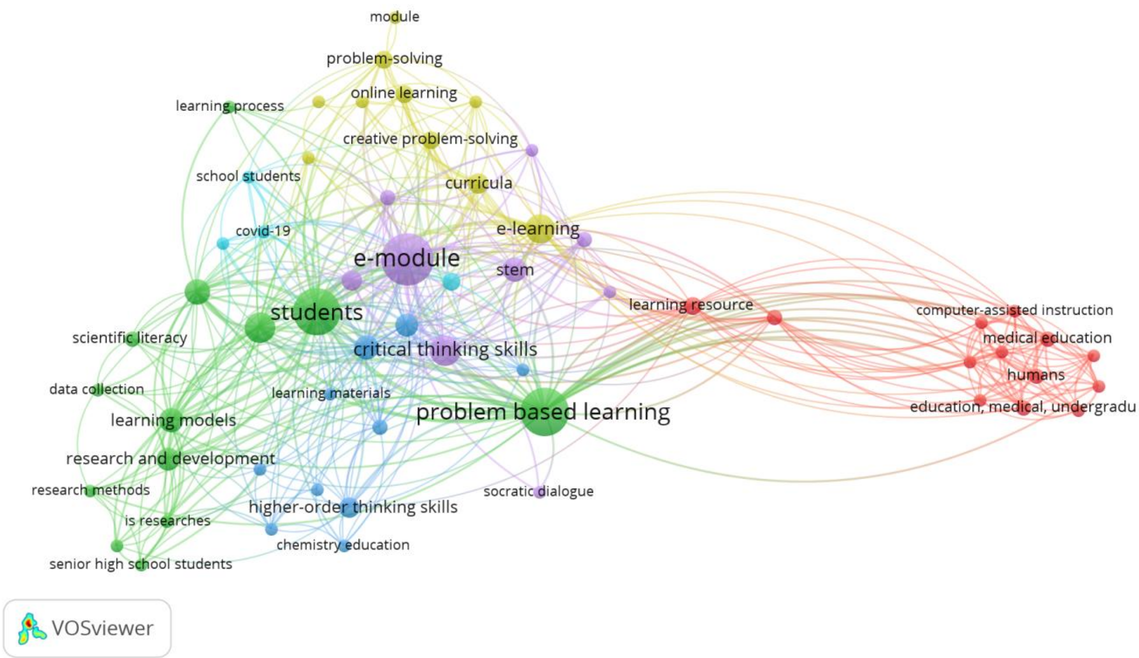

Figure 3. Network Visualization of Research Trends in E-modul and Problem Based Learning for Sustainable Development

Figure 3 shows a network visualization of the bibliometric analysis results that illustrate the relationship between research topics on e-modules and Problem Based Learning (PBL). It can be seen that the keywords “problem based learning” and “e-module” occupy a central position and are closely connected to terms such as students, critical thinking skills, and higher-order thinking skills. This indicates that research in this field focuses on developing higher-order thinking skills through the integration of innovative learning models and digital media. The green and blue clusters emphasize the relationship between PBL, scientific literacy, and research-based learning models, while the purple and yellow clusters indicate the strengthening of e-learning, STEM, and online learning as technological support in learning. The red cluster indicates the relationship of this research to medical education and computer-assisted instruction, indicating the expansion of the application of PBL and e-modules across various disciplines. Overall, this network reflects the dynamic research trends towards 21st-century learning that emphasizes collaboration, problem-solving, and education for sustainable development.

These results indicate that the current research direction focuses on developing interactive e-modules that support problem-based learning to improve students' critical thinking skills and scientific literacy. This finding aligns with research by Safitri et al., (2023) who emphasized the effectiveness of PBL integration in e-modules to improve student response and understanding, as well as Utama, (2025) who found that PBL-based e-modules were able to improve critical thinking and problem-solving skills in physics learning.

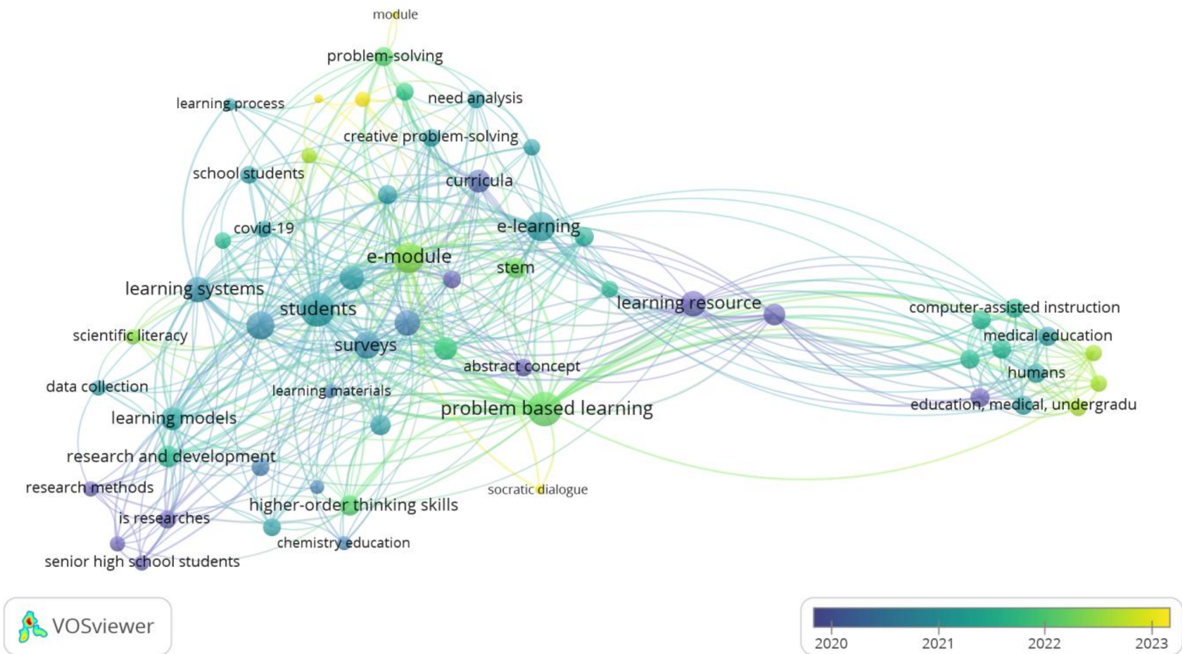

Figure 4. Overlay Visualization of Research Trends in E-modul and Problem Based Learning for Sustainable Development

Figure 4, the overlay visualization image shows the development of research related to the integration of e-modules with the Problem Based Learning (PBL) model in physics learning from 2020 to 2023. The colors in the network depict the publication period, where blue represents earlier research (around 2020), while green to yellow indicate more recent research (2022–2023). Based on the analysis results, the initial research topics focused on learning models, students, learning systems, and research and development. Over time, the research direction shifted towards technology integration and strengthening 21st-century competencies such as e-learning, higher-order thinking skills, and scientific literacy. In the most recent period, a yellow cluster emerged, indicating a new research trend, namely the application of e-modules in the context of problem-solving, medical education, and computer-assisted instruction. This indicates that the focus of current research is starting to move towards the development of PBL-based digital innovations to improve the effectiveness of learning across disciplines, including medicine and STEM.

Overall, this overlay map shows that physics research in recent years has shifted from a conventional focus to innovative and interdisciplinary approaches, with an emphasis on the use of digital technology, active learning models such as Problem-Based Learning, and strengthening students' scientific literacy and critical thinking skills. This trend aligns with the direction of modern physics education, which emphasizes the integration of science, technology, and social contexts to create meaningful and relevant learning for the needs of the 21st century.

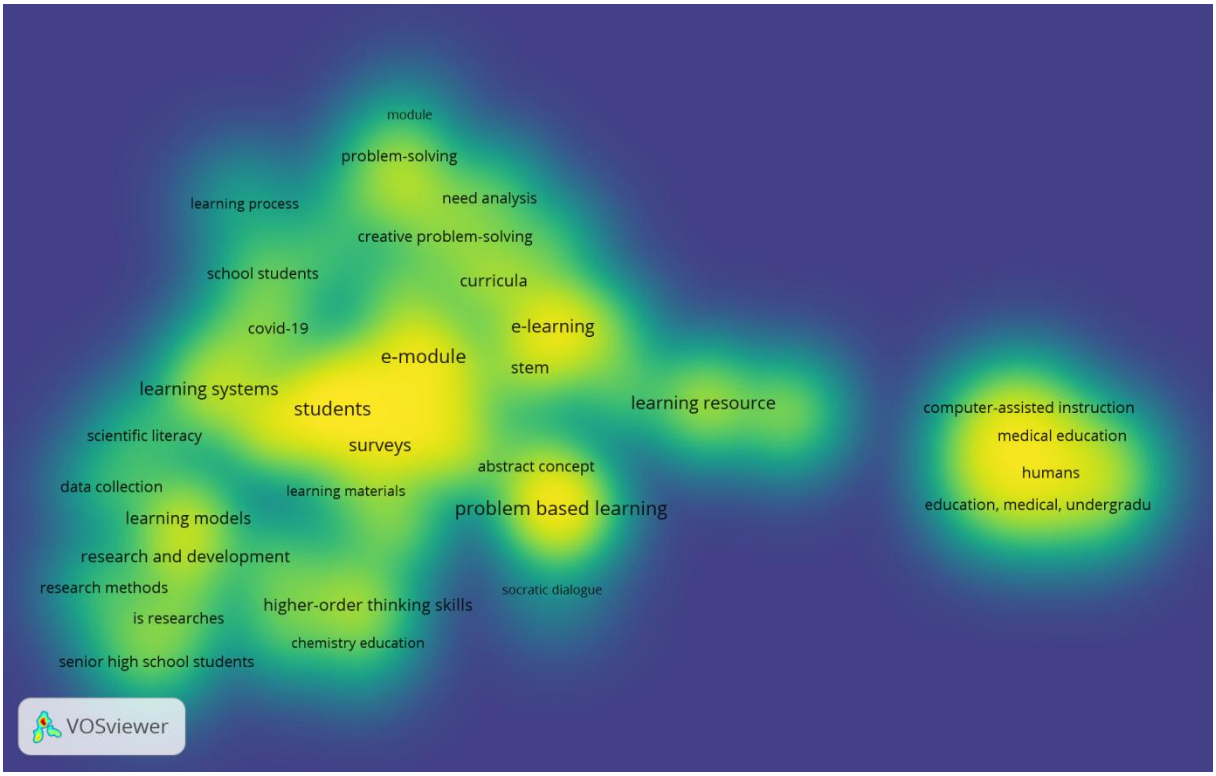

Figure 5. Density Visualization of Research Trends in E-module and Problem Based Learning for Sustainable Development

Figure 5, the density visualization image shows the level of keyword occurrence in research related to the integration of e-modules with Problem-Based Learning (PBL) models in physics learning. Yellow on the map indicates areas with high frequency or the most frequently researched topics, while green to blue colors indicate lower densities. Based on the visualization results, the keywords with the highest density are in the areas of "e-module," "students," "surveys," and "problem-based learning." This indicates that the main focus of the research is centered on developing e-modules integrated with PBL to improve student engagement and learning outcomes. In addition, the keywords "learning systems," "learning resources," and "e-learning" also show a fairly high level of density, indicating a close relationship between the use of learning technology and problem-based learning models. Meanwhile, topics such as "medical education" and "computer-assisted instruction" are in a more separate area but still demonstrate the relevance of cross-disciplinary research that is developing towards the field of medical education and the digitalization of learning.

Overall, this density map shows that current physics research is focused on developing digital learning media and active learning models such as Problem-Based Learning to increase student participation, critical thinking skills, and scientific literacy. This aligns with the demands of 21st-century learning, which emphasizes the importance of technology, collaboration, and contextual approaches to understanding physics concepts more deeply and meaningfully.

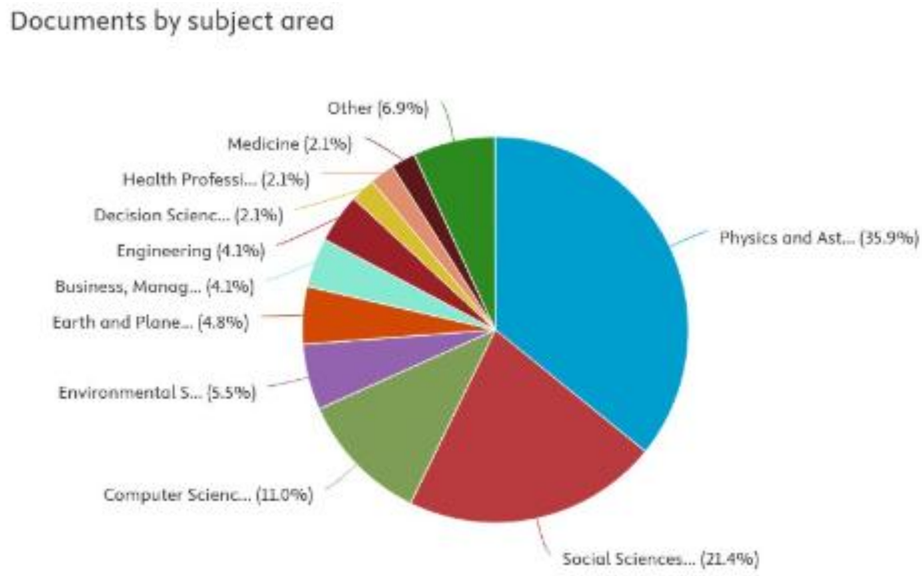

Figure 6. Subject Area Research E-module and Problem Based Learning for Sustainable Development

Figure 6, based on the visualization in the Documents by Subject Area image, research on the integration of e-modules with the Problem Based Learning (PBL) model in physics learning is mostly conducted in the Physics and Astronomy field with a proportion of 35.9%. This shows that the topic of integrating e-modules and PBL has a strong relevance to the development of physics learning that emphasizes problem solving and exploration of scientific concepts. Furthermore, the Social Sciences field is in second place with a contribution of 21.4%, reflecting the attention to pedagogical and social aspects in the implementation of innovative learning models. The Computer Science field also contributed significantly at 11%, indicating the important role of digital technology in the development of e-modules. Meanwhile, other fields such as Environmental Science (5.5%), Earth and Planetary Sciences (4.8%), Engineering (4.1%), and Business, Management and Accounting (4.1%) show cross-disciplinary applications. The fields of Medicine, Health Professions, and Decision Sciences each contributed 2.1%, while the Other category covered 6.9%. Overall, this distribution illustrates that research on the integration of e-modules with PBL models is not only focused on physics, but is also developing in an interdisciplinary direction involving social sciences, technology, and health.

The dominance of physics indicates that research in this field remains a primary focus in the development of science, both in terms of basic concepts and applications in various life contexts. The significant contribution of the social sciences indicates that physics research is now largely directed at developing physics education, particularly in understanding the social and pedagogical aspects that influence students' learning processes. Meanwhile, the involvement of computer science indicates that digital technology has become an important part of physics research and learning, such as through the use of simulations, virtual laboratories, or interactive e-modules. Furthermore, the contribution of environmental science and engineering indicates that physics is also widely applied to address global issues such as climate change, energy, and environmental sustainability. Overall, this diagram demonstrates that physics research is interdisciplinary and continues to evolve, combining various disciplines to deliver innovations relevant to the needs and challenges of the 21st century.

The results of the bibliometric analysis indicate an increase in research attention on the integration of e-modules and Problem Based Learning (PBL) models in physics learning, which is in line with the theoretical framework of innovation diffusion—where the adoption of new technologies and learning models tends to be gradual and reaches momentum when the majority of the academic community begins to use them. This explanation is in line with Rogers' concept of innovation adoption, which emphasizes the stages of knowledge–persuasion–decision–implementation–confirmation as the general process of educational technology adoption.

Theoretically, this finding is also supported by the constructivist foundations of Piaget and Vygotsky: PBL and e-modules encourage active and social learning so that students collaboratively build understanding of physics concepts through real-life case investigations and structured dialogues, in accordance with constructivist principles of meaningful learning and the role of social interaction in cognitive development. Furthermore, the increasing number of publications linking PBL–e-modules to scientific literacy reinforces the relevance of 21st-century learning goals; Bybee and the OECD report emphasize the importance of students' ability to apply scientific concepts in real-world contexts, which is the goal of problem-oriented e-module design (Indrayani et al., 2025; Sumarhadi, 2025).

In a practical context, the network visualization highlights both bottlenecks and opportunities: strong associations between keywords such as students, critical thinking skills, and higher-order thinking skills indicate a strong pedagogical focus, but looser associations with implementation themes (e.g., longitudinal, broad-scale studies, or detailed instructional aspects) indicate a lack of research evaluating sustainability and transfer of learning at a systemic scale (Chen, 2024). This finding is consistent with the literature showing that despite numerous e-module development studies and PBL case studies (including in physics), evidence of long-term sustainability and replication across contexts remains limited (Djudin, 2023).

Based on the synthesis of the findings and theoretical review above, this study found several key points: (1) the topic of integrating e-modules with PBL is a growing research area and is relevant to the goals of scientific literacy and 21st-century skills; (2) preliminary evidence suggests improved problem-solving and critical thinking skills in students learning through PBL-oriented e-modules, but the effects vary across studies; and (3) there is an expansion of cross-disciplinary applications that open up opportunities for interdisciplinary collaboration. Empirical support for these claims can be traced from the e-module development studies and meta-analyses of PBL effectiveness linked in this review (Sikumbang, 2025; Sutisnawati & Uswatun, 2025; Indrayani et al., 2025)

However, this bibliometric study has limitations that should be noted. First, the database used is limited to Scopus, so there may be relevant research in other databases (e.g., ERIC, Web of Science, or local repositories) that was not covered by this analysis—this limitation has the potential to introduce bias in thematic representation. Second, the time limit (2017–2025), keyword selection, and data extraction parameters (e.g., keyword frequency threshold, synonym processing) affected the scope of the network formed;

different VOSviewer settings may have resulted in slightly different clusters. Third, bibliometrics are not a substitute for in-depth qualitative analysis—e.g., i-case studies assessing pedagogical design, e-module quality, or primary learning outcome data are needed to validate bibliometric interpretations. Fourth, the dominance of publications in a particular language (English or the national language) may introduce linguistic bias in the research map. Therefore, recommendations for future research include conducting a systematic/qualitative review of primary studies, expanding the database, and designing experimental/longitudinal empirical studies to test the effectiveness and sustainability of PBL e-module integration in physics learning (S. S. Wulandari & Surabaya, 2023).

CONCLUTION

Based on the bibliometric analysis, it can be concluded that research on the integration of e-modules with the Problem-Based Learning (PBL) model in physics learning has shown a significant and consistent increase from 2017 to 2025, reflecting growing interest in innovative, technology-based, and student-centered learning approaches. The dominant keywords such as *e-module*, *problem-based learning*, *students*, and *critical thinking skills* indicate a strong focus on improving students' problem-solving abilities and scientific literacy through digital innovation. Research topics have evolved from general learning systems to technology-integrated and interdisciplinary studies, involving not only physics but also fields such as computer science, social sciences, and medical education. The subject area analysis shows that physics remains the primary focus (35.9%), followed by social sciences (21.4%) and computer science (11%), illustrating the interdisciplinary nature of this topic. Overall, the integration of e-modules with the PBL model is proven to be a promising innovation in transforming physics education into a more active, contextual, and relevant form of learning aligned with 21st-century educational demands.

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