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The Potential of E-Learning in Understanding Concepts in Science and Physics Education: A Bibliometric Analysis

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ABSTRACT

Objective: *The objective of this study is to describe trends, contributions, developments, and research opportunities in e-learning for conceptual understanding in physics and science education.* ***Method:*** *The research method employed was bibliometric analysis using the Scopus database. Data were obtained from the Scopus database using the search terms "E-Learning" AND "Physics Education" OR "Science Education" AND "Conceptual Understanding," yielding 2,735 documents. The Scopus database was filtered by year, document type, and language, resulting in 2,363 documents for analysis.* ***Results:*** *The results indicate that research on e-learning's impact on conceptual understanding in physics or science education has been a trend over the past ten years. The top contributing authors are H, Gwo-Jen; S, Niwat; K, Heru; and S, Andi, while the top affiliations are Indonesia University of Education, Padang State University, and Malang State University. Current developments in e-learning have been categorized as artificial intelligence, so the opportunity for data-driven research lies in developing artificial intelligence for learning.* ***Novelty:*** *Technological transformation has impacted the world of education, particularly in strategies to improve students' conceptual understanding. This study presents a bibliometric mapping of e-learning research related to conceptual understanding in physics and science education. This study differs from previous research, which has not presented a thematic evolution to guide future research.*

INTRODUCTION

In the transition from Industry 4.0 to Society 5.0, significant advances in digital technology have been made. These technological advancements have a significant impact on human well-being, particularly in education. The use of technology is expected to create an educational system that is more adaptive, innovative, and responsive to 21st-century learning needs. Integrating technology into the learning process can enhance the quality of interaction between educators and students through various interactive digital media (Alenezi et al., 2023; Sari et al., 2025). With the support of technology, the learning process not only takes place conventionally but also utilizes various digital platforms that support learning activities (Josué et al., 2023). This indicates that integrating technology is expected to help students hone their skills, particularly their conceptual understanding. Therefore, the use of technology in education is a strategic step in improving the quality of learning in the digital age, particularly in enhancing conceptual understanding (Bond et al., 2021).

Achievements through digital technology are expected to provide quality education that fosters students' ability to understand concepts in depth (Rahmah & Lubis, 2024). Conceptual understanding is expected to help students connect the knowledge they have learned to various phenomena in their surrounding environment. With a solid conceptual understanding, students do not merely memorize learning materials but can also explain, interpret, and apply these concepts in various situations (Arsyad & Syakhrani, 2024). This ability serves as a primary indicator of meaningful learning. Furthermore, conceptual understanding is also expected to support the development of critical thinking, analytical, and problem-solving skills. Therefore, the learning process must be designed to encourage students to actively and deeply build conceptual understanding. Consequently, enhancing students' conceptual understanding is a primary goal in the pursuit of quality education (Hansen, 2023), particularly in understanding scientific concepts related to the natural world.

One area of learning that requires a deep conceptual understanding is science, particularly physics. Physics examines various natural phenomena, explaining them through scientific concepts that are often abstract and complex. In school settings, many students still struggle to fully grasp physics concepts (Aksit & Wiebe, 2020). This situation leads students to tend to memorize formulas without understanding the underlying concepts (Nilimaa, 2023). Consequently, students often struggle when faced with problems that require applying these concepts in specific contexts. Several studies indicate that a lack of understanding of physics concepts remains one of the primary challenges in science education at all educational levels. This suggests that physics instruction still needs improvement to help students understand these concepts more deeply. Therefore, a teaching approach is needed to support students' understanding of physics concepts (Herlina et al., 2023). In this context, digital technology is particularly needed in physics learning to enhance conceptual understanding.

With the advancement of digital technology, modern education has begun to utilize various e-learning platforms to support the learning process. E-learning allows students to access learning materials flexibly through digital devices and the internet (Santiago et al., 2021; Laili & Nisa, 2025). Additionally, e-learning offers interactive features such as instructional videos, virtual simulations, discussion forums, and online quizzes that help students gain a deeper understanding of the material. In science and physics education, e-learning can also help visualize abstract concepts, making them easier for students to understand. Various studies indicate that e-learning can enhance student engagement in the learning process (Panigrahi et al., 2021). Nevertheless, the implementation of e-learning in education still requires further development to be optimally utilized in supporting students' conceptual understanding. Therefore, e-learning has become an important alternative in modern education (Dhawan, 2022).

Although research on e-learning in education continues to grow, studies that specifically map the development of this research remain limited (Djeki et al., 2022). Most previous studies have focused more on the development of instructional media or

on testing the effectiveness of e-learning in improving learning outcomes (Logan et al., 2021). However, research analyzing development trends, researcher collaboration, and relationships between research topics in the field of e-learning has not been extensively conducted. However, research mapping is crucial for providing an overview of the direction of scientific research development within a specific field. Through research mapping, researchers can identify topics that have been extensively studied and uncover research gaps that still need to be explored. Furthermore, research mapping can help understand the dynamics of scientific literature development in the field of e-learning. Therefore, a study is needed to map the development of e-learning research and support a systematic and comprehensive understanding of the concepts (Donthu et al., 2021).

Based on this research gap, this study offers a bibliometric analysis to map the development of research on e-learning in supporting conceptual understanding. Bibliometric analysis is a method for quantitatively analyzing scientific literature using indicators such as the number of publications, author collaboration networks, and the evolution of research keywords (Hassan & Duarte, 2024). Through this approach, the study can provide an overview of research trends, emerging topics, and researchers' contributions within a specific field of study. Previous research has presented only visualizations of bibliometric analyses on e-learning and conceptual understanding (Djeki et al., 2022). The uniqueness of this study lies in its use of bibliometric analysis to systematically examine the development of e-learning research on conceptual understanding in learning.

Additionally, this study presents a visual mapping of the relationships among emerging research topics in this field. Furthermore, this study provides a thematic visualization of research evolution to track its development. The results of this study are expected to provide comprehensive information on the direction of research development and opportunities for future studies. Thus, this study can serve as an important reference for researchers seeking to advance research on e-learning in education.

RQ1: What are the current trends and contributions of e-learning research to conceptual understanding in physics and science education?

RQ2: How has e-learning research on conceptual understanding in physics and science education evolved over time?

RQ3: What are the opportunities for e-learning research on conceptual understanding in physics and science education on an international scale?

RESEARCH METHOD

Information Source

This study uses the Scopus database for information retrieval and bibliometric analysis. Bibliometrics is used to analyze the mapping and evaluation of research relevant to current conditions (Krisanti et al., 2025). Therefore, the objective of this

study aligns with the bibliometric research method. The reason for using the Scopus database is its broad coverage of scientific literature across various disciplines, making it ideal for comprehensive literature reviews (Zhu et al., 2024). Furthermore, the Scopus database provides information for evaluating research within the desired field of coverage (Asubiaro, 2023; Yeung, 2021). This is the basis for researchers to use the Scopus database to identify gaps and opportunities for further research.

In this context, researchers did not use Google Scholar for their search because of the lack of abstract information, which is necessary for topic modeling analysis (Asl et al., 2023). The literature search focused on articles related to e-learning and conceptual understanding in physics education. The database search was conducted using "E-Learning" AND "Physics Education" OR "Science Education" AND "Conceptual Understanding," which yielded 2735 documents.

Eligibility Criteria

Data collection and elaboration were conducted at March, 2026 through the Scopus database. The criteria for document selection are as follows:

1. Time Frame: eligible data includes research data collected over the last 10 years, so the data included in the criteria is from 2015-2025.
2. Language: Eligible data includes research conducted in English; therefore, research conducted in languages other than English is not included in the data criteria.
3. Document Type: The eligible data collected consists of documents classified as articles, conference papers, book chapters, reviews, and books.

Furthermore, data clustering is based on the type of document obtained from the Scopus database, as shown in Figure 1.

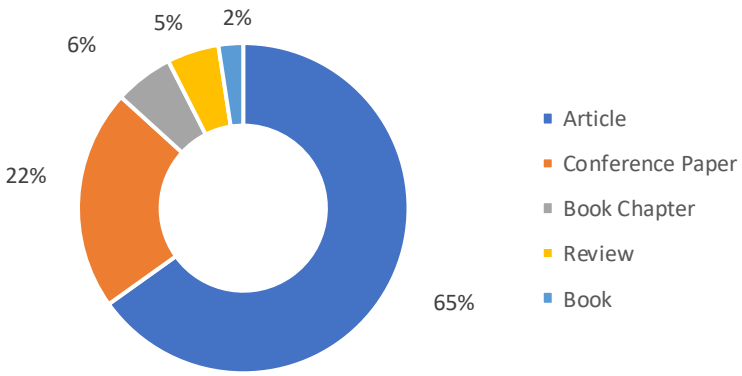

Figure 1. Document type

Data Collection

The database search was conducted through a broad search with specific criteria. Subsequently, data filtering was performed, for example, based on year (the last 10 years), document type, and language (English). This systematic approach ensures that the search was comprehensive, covering many relevant studies. The screening process

for the selected documents covers a 10-year period because the researchers wanted to identify trends in research over the past 10 years. English was used as the language filter because it is a widely used international language. The document types were selected because the researchers wanted to identify opportunities for scientific publication in the form of articles, conference papers, book chapters, reviews, and books. Clustering by year, language, and document type helps identify opportunities in international publications (Cozzoline & Ferraro, 2022). Menurut Meirbekov et al. (2024) The language has been used over the past 10 years because it is well-suited to our needs, while English is used because it is an international language and therefore easier to use. For further details, the database collection process can be seen in Figure 2.

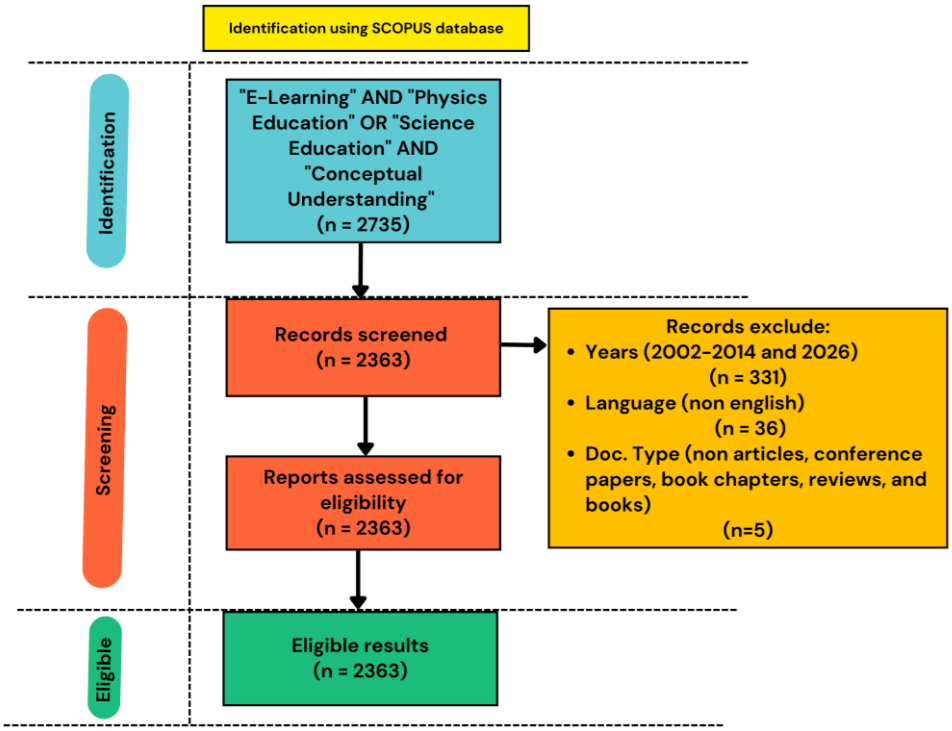

Figure 2. Screening process

Data Analysis

The raw data was initially exported from Microsoft Excel as a CSV file, listing the author's name, affiliation, position, country, journal title, and keywords. The next step involved descriptive analysis tailored to answer our research questions. For data visualization, we used Bibliometrix in R Studio. These programs together provide various analytical functions that allow us to study indicators such as the total number of publications, the number of citations, author collaboration networks, and co-occurrence patterns among keywords (Srivastava & Srivastava, 2022; Wani & Ganaie, 2024). Through these programs, researchers can identify developments, trends, opportunities, and the contributions of e-learning to conceptual understanding in physics or science education on an international scale.

RESULTS AND DISCUSSION

Results

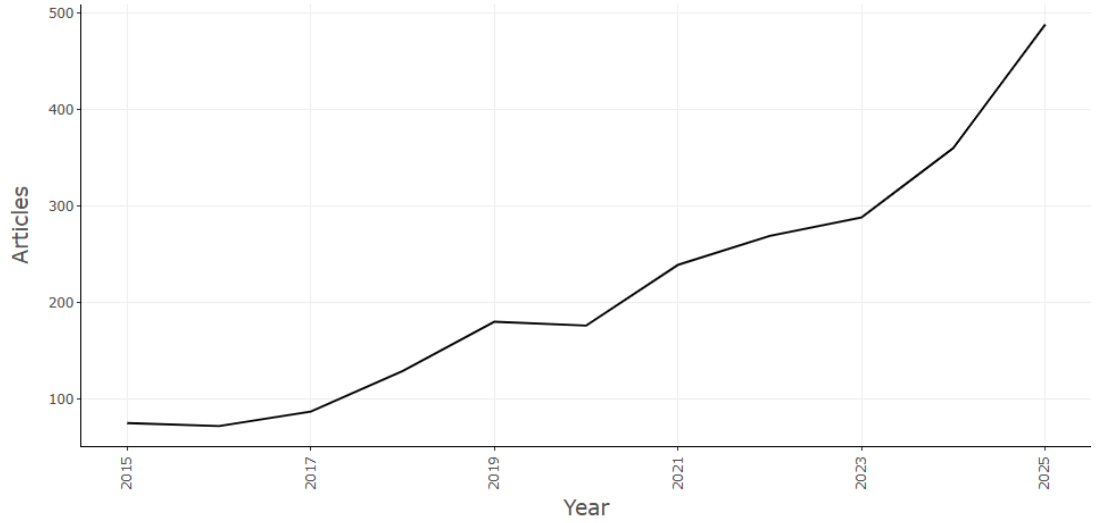

Figure 3. Annual productivity

Figure 3 shows that research on e-learning for conceptual understanding in physics and science education has increased over the past 10 years. This growth is evidenced by nearly 500 research documents indexed in Scopus over the last decade. This indicates that research on e-learning for conceptual understanding in physics and science education is a growing trend. The annual increase in research documents evidences this. Furthermore, the data obtained indicate that e-learning in physics and science education is necessary to enhance students' conceptual understanding (Banda & Nzabahimana, 2021). In this regard, the findings highlight the importance of integrating technology into education.

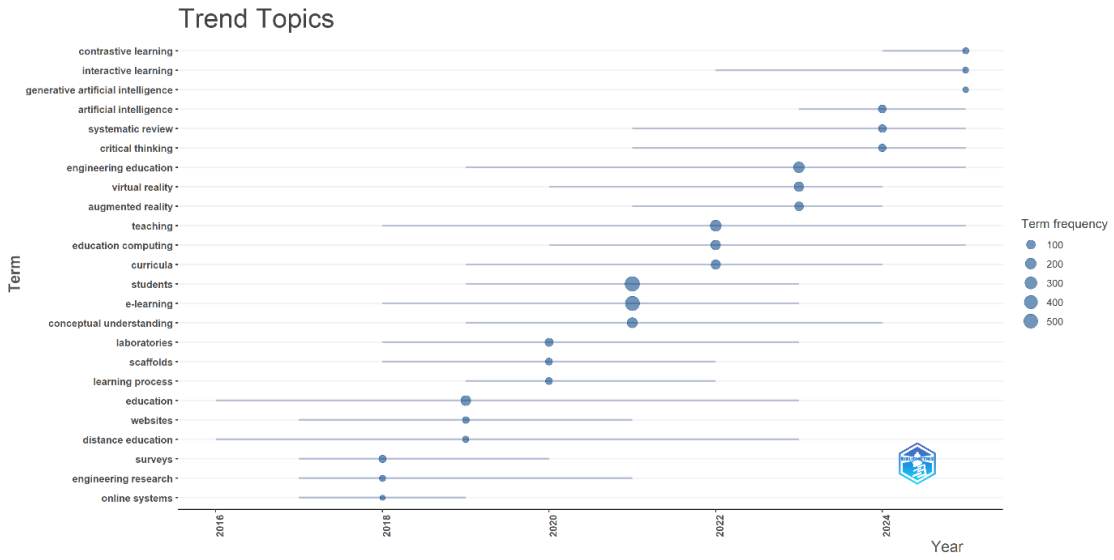

Figure 4. Annual research trends

Based on Figure 4, the keywords "e-learning" and "conceptual understanding" were trending in 2021. This finding is based on the term frequency of "e-learning" in 2021, which appeared in 400 documents, compared with "conceptual understanding," which

appeared in 200 documents. Furthermore, the keyword "e-learning" shows a trend from 2018 to 2023, as evidenced by the gray line in Figure 4. The keyword "conceptual understanding" shows a trend from 2019 to 2024, indicated by the gray line. Although these keywords have blue circles in 2021, the trend is reinforced by the gray lines. The blue circle indicates the year with the most documents, resulting in the blue circle visualization. In this context, it remains relevant for developing e-learning focused on conceptual understanding. Furthermore, the keywords "physics" or "science education" are not visible in the trending topic visualization; therefore, if you wish to explore new topics for discussion, you can add keywords related to physics or science education.

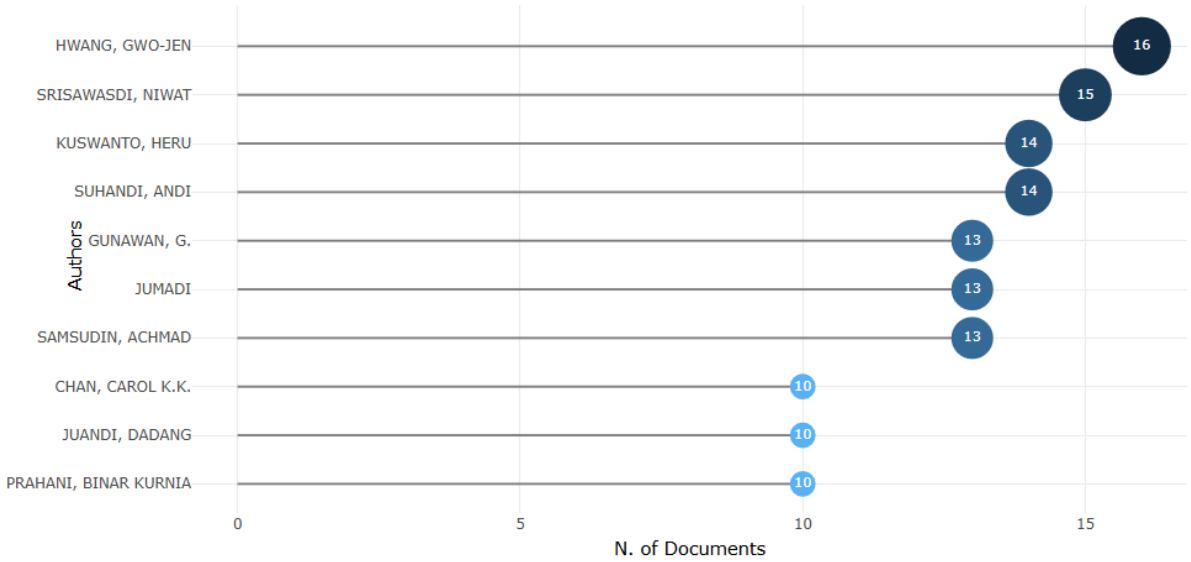

Figure 5. Top contributing authors

Based on Figure 5, the top authors contributing to research on e-learning for conceptual understanding in physics and science education are H Gwo-Jen, Niwat, Heru, and S Andi. H Gwo-Jen contributed 16 research papers related to e-learning for conceptual understanding in physics and science education. S Niwat contributed 15 documents, while K Heru and S Andi contributed 14 documents each. These top authors have published more than 13 research documents, thus making a significant contribution to the research. In this context, these top authors have made significant contributions and have major implications for conducting e-learning research on conceptual understanding in physics and science education.

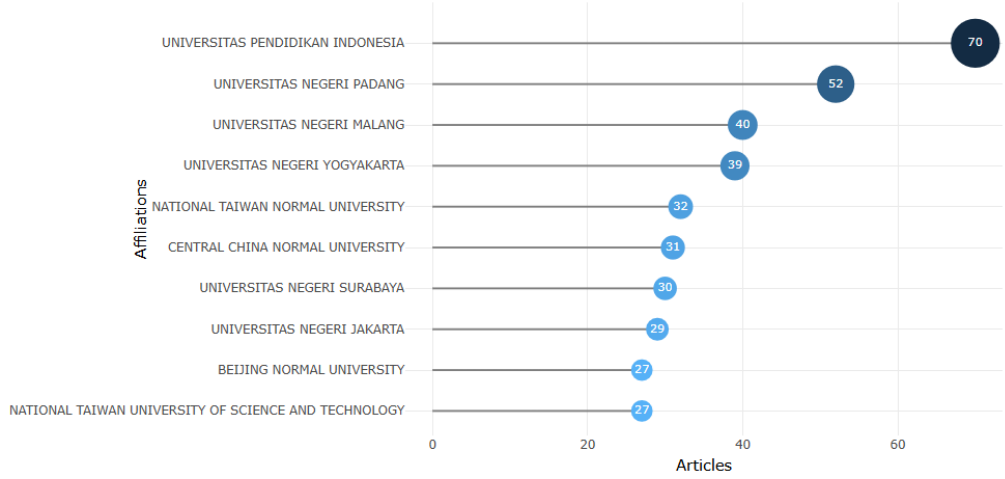

Figure 6. Top affiliate contributions

Based on Figure 6, the top three institutions contributing to e-learning research on conceptual understanding in physics and science education are the Indonesia University of Education, Padang State University, and Malang State University. The Indonesia University of Education contributed 70 research documents related to e-learning for conceptual understanding in physics and science education. Padang State University contributed 52 documents, while Malang State University contributed 40 documents. These top institutions have more than 40 research documents each, thus making a significant contribution to the research. In this context, these top institutions have made significant contributions and have major implications for conducting e-learning research on conceptual understanding in physics and science education.

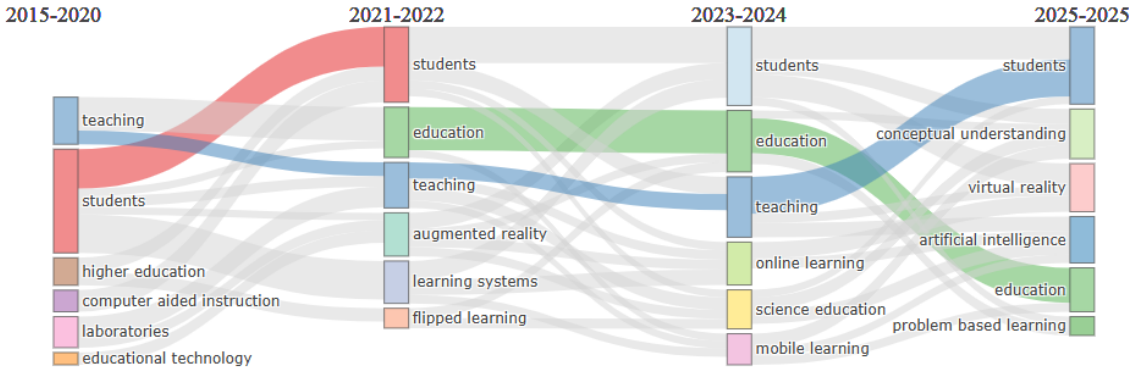

Figure 7. Thematic evolution

To further explore the research findings, a thematic evolution analysis, as shown in Figure 7, is necessary. The thematic evolution in Figure 7 is divided into four periods: 2015–2020, 2021–2022, 2023–2024, and 2025. During the 2015–2020 period, an interesting finding emerged: research using the keywords "teaching," "students," and "laboratories" was more dominant. During the 2021–2022 period, these three keywords branched out into new areas, evolving into the keywords "augmented reality" and "education." In the 2023–2024 period, these keywords expanded into research on "online learning," "science education," and "mobile learning." By 2025, these keywords

have evolved into "conceptual understanding" and "artificial intelligence." In this context, it is evident that future research should focus on e-learning that supports conceptual understanding. Additionally, artificial intelligence is poised to become a key component of e-learning development in the coming years. According to Cheah (2021) and Maghligawati et al. (2023), the utilization of artificial intelligence in e-learning is essential for enhancing students' conceptual understanding, particularly in physics and science education.

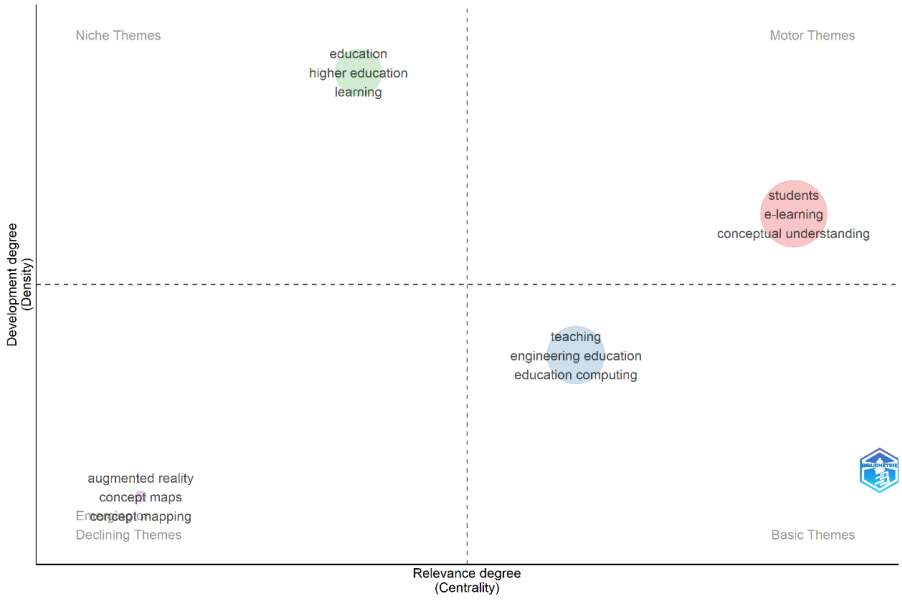

Figure 8. Thematic map

Figure 8 illustrates a thematic map of e-learning research on conceptual understanding in physics and science education. Based on Figure 8, several interesting points emerge: research on e-learning and conceptual understanding is highly relevant. Meanwhile, physics and science education are absent from the visual representation; instead, the keyword "education" appears. The research findings indicate a gap, as research on e-learning and conceptual understanding is indeed relevant and has advanced significantly. Research on physics and science education has not yet emerged because there is currently no established relevance or significant development in this area. In this context, there is a need to develop research that connects e-learning and conceptual understanding in physics and science education. These results demonstrate that deeper innovation is required in developing research on e-learning and conceptual understanding in physics and science education. To integrate these elements, future researchers can focus on applying e-learning and conceptual understanding to physics and science education.

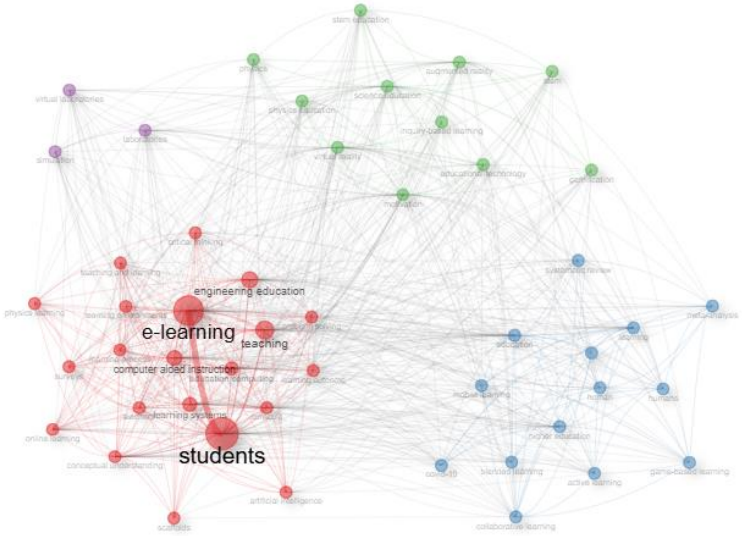

Figure 9. Network visualization

Based on Figure 9, the main keywords conceptual understanding, e-learning, and physics education are located in two clusters. The keywords conceptual understanding and e-learning are located in the red cluster, while physics education is located in the green cluster. The findings indicate that "physics education" is not located in the red cluster, meaning the keyword "physics education" still has a distant relationship with "e-learning" and "conceptual understanding." Furthermore, within the red cluster, the keyword "conceptual understanding" is not dominant in the cluster mapping. These findings suggest a gap in the primary keywords within the search. In this context, it is evident that a combination of these three main keywords is necessary for future research. According to Liu et al. (2021), the novelty of research can be established by analyzing bibliometrics through research gaps in network visualizations. In this context, future researchers can further align and develop e-learning research for conceptual understanding in physics education, thereby creating opportunities for future research.

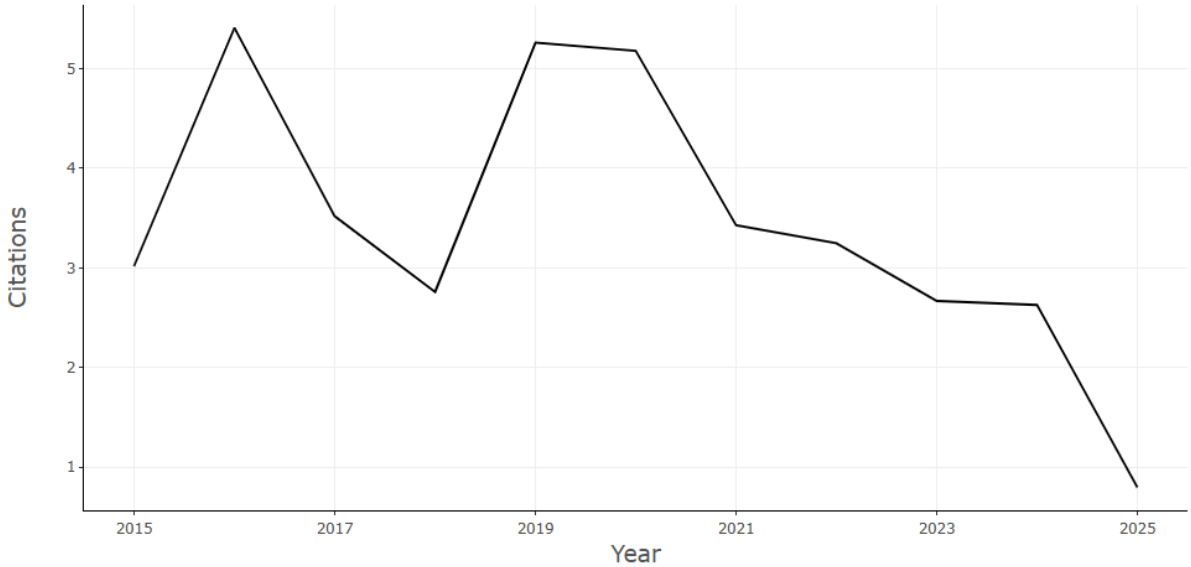

Figure 10. Total citations per year

Table 1. Average research citations

MeanTCperArt	N	Year	MeanTCperYear	CitableYears
36.27	75	2015	3.02	12
59.51	72	2016	5.41	11
35.24	87	2017	3.52	10
24.84	129	2018	2.76	9
42.04	180	2019	5.26	8
36.27	176	2020	5.18	7
20.55	239	2021	3.43	6
16.26	269	2022	3.25	5
10.68	288	2023	2.67	4
7.90	360	2024	2.63	3
1.59	488	2025	0.80	2

Description:
Mean TCperArt: Average citations per article
N: Number of documents
Mean TCperYear: Average citations per year
Citable Years: Number of years an article can be cited

Figure 10 and Table 1 show the citation potential for research on e-learning for conceptual understanding in physics and science education. Figure 10 indicates that the number of citations for e-learning research on conceptual understanding in physics and science education has declined. From 2020 to 2024, there was a decline in the number of citations for e-learning research on conceptual understanding in physics and science education. In 2016, e-learning research on conceptual understanding in physics and science education had the highest number of citations compared to 2019. This was due to the need for technological innovation in education through digitalization. In 2025, the number of citations is low because the documented materials are still new. This is evidenced by the years cited, meaning that in 2025 or the following year, there will only be opportunities for 2 articles. As shown in Table 1, there is an increase in the number of cited documents. The number of cited documents indicates the need for relevant references regarding e-learning and conceptual understanding in future research (Fauzi, 2022; Negahban & Zarifsanaiey, 2020). In this context, e-learning research aimed at enhancing conceptual understanding in physics and science education will have a high likelihood of being cited if it introduces something new and unique. To capitalize on this opportunity, the research must offer something novel with a specific and unique focus, such as studies that emphasize the context of artificial intelligence.

Discussion

The findings indicate that research on e-learning for conceptual understanding in physics and science education is trending strongly. This is evidenced by the data in Figures 3 and 4, which show an increase in the number of research documents identified. Research trends indicate the relevance of studies conducted within the field of Education. Research on e-learning and conceptual understanding in physics or science education is currently essential because the outcomes contribute to global

development (Damarsha et al., 2025; Naufal et al., 2025). Furthermore, in the technological era, digital technology that can contribute to building education through conceptual understanding is highly needed (Olszewski & Crompton, 2020). This is what makes such research trending and relevant, thereby aligning with the need for research innovation. Advances in e-learning technology will continue to grow in response to human needs, while conceptual understanding will improve as the foundation for critical thinking skills.

The findings also indicate an evolutionary development in e-learning research aimed at enhancing conceptual understanding in physics and science education. These findings are supported by Figures 7 and 8, which visualize the development across four periods, as well as the mapping diagram. Further development of the relevance of existing research is needed. In the findings, the keywords "physics" or "science" do not appear in the visualization of Figure 8, which means that research using these keywords has not yet demonstrated research relevance. This presents an opportunity for new research to incorporate the terms "physics" or "science education" into e-learning research for conceptual understanding. The thematic evolution suggests that e-learning could evolve into artificial intelligence for future research. The need for artificial intelligence is growing stronger, and its innovations are increasing (Yu et al., 2022). In this context, the development of artificial intelligence as an e-learning tool is necessary to enhance conceptual understanding, particularly in physics or science education (Cheah, 2021; Maghligawati et al., 2023).

The findings of this research on e-learning for conceptual understanding in physics and science education indicate significant potential. Figure 9 shows that there is a research gap regarding key terms, presenting an opportunity for innovative advancements. The number of cited documents indicates a significant increase in the relevance of this research. To further capitalize on these opportunities, innovations in e-learning-based artificial intelligence are needed to enhance conceptual understanding. In this context, this will open opportunities for international-scale publications in the field of education. In the utilization of e-learning technology, artificial intelligence elements are needed to ensure relevance to the evolving world of education and technology.

This study differs from previous research in that it provides a visualization of the relevance and opportunities for conducting e-learning research aimed at enhancing conceptual understanding in physics and science education. Unlike the studies by Le et al. (2025) and Krisanti et al. (2025), which focused solely on describing research databases and network visualizations rather than visualizing research trends. This study aims to contribute to technology-integrated learning by enhancing conceptual understanding of physics or science. With the growing body of research on e-learning and conceptual understanding, the hope is that technology can help foster quality education—specifically SDG 4. Therefore, there is a need for e-learning innovations to enhance conceptual understanding, particularly in physics education. A limitation of

this study is the narrow time frame of the bibliometric data, which spans only 10 years; therefore, further expansion is needed in analyzing bibliometric themes.

CONCLUSION

Fundamental Finding : The results of this study indicate that e-learning research aimed at enhancing conceptual understanding in physics and science education is a growing trend. This trend is supported by findings of an increase in the number of documents over the past ten years in the Scopus database. The research results indicate that H, Gwo-Jen; S, Niwat; K, Heru; and S, Andi are the authors who have contributed to e-learning research on conceptual understanding in physics and science education by publishing more than 13 scientific articles. Institutions that have contributed include the Indonesia University of Education; Padang State University; and Malang State University, which have published more than 40 scientific articles in the field of e-learning for conceptual understanding in physics and science education. There has been development in e-learning-based artificial intelligence within thematic evolution, presenting an opportunity for future researchers to study e-learning for conceptual understanding in physics and science education. Research opportunities on an international scale are significant due to gaps in the three main keywords. This serves as a foundation for future researchers to conduct studies on e-learning for conceptual understanding in physics and science education. **Implication :** This study aims to contribute to technology-integrated learning in enhancing the understanding of physics or science concepts. Additionally, this study aims to support the SDGs, particularly SDG 4 on quality education, through the integration of technology. **Limitation :** A limitation of this study is that the time frame used in the bibliometric analysis is limited to 10 years. Furthermore, this study is limited to providing a visualization of the bibliometric analysis. **Future Research :** Future research is expected to expand the years covered in the bibliometric analysis and employ a systematic literature review to analyze the impact thematically.

AUTHOR CONTRIBUTIONS

Adrian Bagas Damarsha: Conceptualization, Investigation, and Visualization; **Nadi Suprapto**: Conceptualization, Validation, and Visualization; **Elvia Reza Lutfiani**: Methodology and Writing - Original Draft; **Siti Nur Aisah**: Methodology and Writing - Original Draft; **Husni Mubarok**: Resources, Data Curation, and Writing - Review & Editing; **Alif Syaiful Adam**: Resources, Data Curation, and Writing - Review & Editing

CONFLICT OF INTEREST STATEMENT

There are no conflicts of interest.

ETHICAL COMPLIANCE STATEMENT

This manuscript complies with research and publication ethics. The authors affirm that the work is original, conducted with academic integrity, and free from any unethical practices, including plagiarism.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

The authors acknowledge the use of digital tools, including AI-based technologies, as support in the research and writing stages of this article. Specifically, [Deepl] was employed for [Translated Language]

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