IJSES 2(1) (2025)

International Journal of Science Education and Science

https://journals.balaipublikasi.id

Systematic Review of Research Trends on Critical Thinking Skills in Physics Learning

Kurnia Julianti Arni[1]

[1] Master of Sciences Education Study Program, University of Mataram, Mataram, Indonesia.

Received: December 3, 2024
Revised: March 12, 2025
Accepted: March 25, 2025
Published: March 31, 2025

Corresponding Author:
Kurnia Julianti Arni
kurniajulianti929@gmail.com

DOI: 10.56566/ijses.v2i1.262

Abstract: This study aims to analyze the research trends of critical thinking skills in physics learning indexed by Google Scholar during the period 2015-2024. Critical thinking skills are an important competency in physics and science education in the 21st century because of its ability to improve conceptual understanding and solve complex problems. Using descriptive methods and bibliometric analysis through VOSviewer software, this study identified patterns and trends in 1,000 indexed documents. The results showed that there was a significant increase in the number of publications related to critical thinking skills, especially in the application of problem-based learning (PBL) and the use of technology in learning. In 2023, the number of publications peaked before declining in 2024. This study also identified six dominant types of publications, with scientific articles being the most widely published. The main keywords that emerged in this trend include "PBL" "critical thinking skills", and "model". These findings are expected to provide insight into the development of research and innovation needed to improve students' critical thinking skills in the future.

Keywords: Bibliometric analysis; Critical thinking skills; Google scholar; Physics learning; VOSviewer

Introduction

Critical thinking skills are one of the most important competencies to have in physics and science education in general in the 21st century. These skills enable students to not only understand physics concepts in depth, but students can apply analytical thinking in evaluating information and solving complex problems. Physics learning provides an ideal context for the development of critical thinking skills because physics learning itself requires an understanding of abstract concepts that must be applied in various real situations (Ennis, 2018). The importance of critical thinking skills in physics education is not only seen in students' ability to understand theoretical concepts, but also in the application of complex analysis and problem solving in real life. Research shows that critical thinking skills support students in developing a deep understanding of physics and science phenomena, followed by the ability to make evidence-based decisions and evaluate information more critically (Baker, 2022). Furthermore, these skills enable students to better navigate the challenges of the modern world, as students with critical thinking skills tend to perform better in physics analysis-based tasks, particularly in the deduction and induction aspects often required in science (Franco-Mariscal, 2024).

Since 2015, there has been a significant increase in research focused on developing critical thinking skills in physics learning. This increase reflects the need for modern education that increasingly emphasizes higher-order thinking skills and problem solving within a scientific framework. For example, the problem-based learning (PBL) approach has been shown to be effective in improving students' critical thinking skills. PBL places students in situations that require them to critically analyze problems and make informed decisions (Farisi et al., 2017; Holmes, 2023). Other studies have also

How to Cite:
Arni, K. J. (2025). Systematic Review of Research Trends on Critical Thinking Skills in Physics Learning. *International Journal of Science Education and Science*, *2*(1), 43–52. https://doi.org/10.56566/ijses.v2i1.262

shown that the use of guided inquiry methods and laboratory experiments that require independent decision-making can improve students' critical thinking skills (Firmansyah, 2017; Rauf et al., 2022).

In recent years, the use of digital technology in physics learning has become increasingly popular, along with efforts to strengthen students' critical thinking skills. A study by Pedraja-Rejas et al. (2024) revealed that the application of mobile learning-based technology not only helps in increasing student engagement but also encourages their critical thinking through deeper interaction with learning materials. This trend continues to grow with more and more studies exploring the integration of technology in physics learning to develop critical thinking skills (Rahayuni, 2016; Satria, 2018).

Research on the application of the Problem-Based Learning (PBL) model and the use of technology in physics learning has increased significantly, especially in the context of critical thinking skills. Bibliometric analysis indicates that the PBL approach in physics learning not only improves problem-solving skills but also critical thinking skills through collaborative activities and real-world problem solving. This trend is seen in several studies, where the implementation of PBL in a virtual collaborative environment allows students to develop cognitive skills such as analysis and inference, which has a positive impact on their learning outcomes (Salazar et al., 2023). In addition, studies have shown that the use of technology such as digital-based PBL modules and physics simulations helps students understand concepts in depth and improve critical thinking skills. A systematic study conducted by Lin et al. (2022) revealed that the adoption of PBL in combination with learning technologies, including simulations and virtual collaborative environments, showed better results in terms of student engagement and learning effectiveness compared to traditional methods.

The Problem-Based Learning (PBL) approach combined with technology has been shown to improve students' critical thinking skills. Afacan et al. (2019) revealed that interaction with real-world context-based problems in technology-based PBL facilitates more effective collaborative learning. Demirkol (2016) added that PBL encourages students to explore solutions and analyze results, thereby increasing deep understanding. Hattie (2019) showed that technology in PBL has a significant impact on learning outcomes, including critical thinking skills. Asoodar et al. (2016) asserted that technology-based PBL helps students connect theory with practical applications, while Stefanou et al. (2004) highlighted the importance of analyzing and synthesizing information in solving complex problems. Tsai et al. (2019) showed that digital simulations in PBL allow for the exploration of diverse solutions, thereby strengthening critical thinking skills. Other studies also highlight the increasing trend of publications focusing on the application of PBL and Project-Based Learning (PjBL) in physics education, which point to the use of technology to develop students' higher-order thinking skills, such as critical and creative thinking (Maysyaroh et al., 2021).

This systematic review of research trends from 2015 to 2024 will provide insight into how new approaches in physics learning have contributed to the development of critical thinking skills. In addition, this study is also expected to identify challenges faced and provide recommendations for further innovation in physics education.

Method

This research method is descriptive and analytical, which aims to understand and describe research trends on critical thinking skills in physics learning. The data used in this study were obtained from information sources indexed by Google Scholar using analysis tools such as Publish or Perish 8 and Dimension.ai. To conduct a search on Google Scholar, the keywords used are keywords related to research trends on critical thinking skills in physics learning.

In this study, an analysis was carried out on 1,000 documents that had been indexed by Google Scholar between 2015 and 2024. The reason for choosing Google Scholar as a source for document search is because Google Scholar applies consistent standards in selecting documents to be included in its index and also because Google Scholar has more documents than other major databases, especially in the context of research in education.

The analysis used is bibliometric analysis using VOSviewer software. VOSviewer has become one of the main software in bibliometric analysis because of its ability to map complex bibliometric networks, such as co-citation, co-authorship, and co-word, and produce big data visualizations quickly (Van Eck et al., 2010). Developed by van Eck et al. (2010), this tool supports multiple data sources including Web of Science, Scopus, and PubMed, and accepts a variety of standard formats that facilitate the integration of data from different databases (Singapore Management University, 2022). VOSviewer uses a distance-based visual mapping technique that positions items based on their degree of similarity, helping users understand relationships between literature more intuitively (Marzi et al., 2025; Van Eck et al., 2010). The use of VOSviewer software in this study aims to conduct bibliometric analysis. VOSviewer was chosen because of its ability to visualize bibliometric networks, such as co-citation, bibliographic coupling, and co-authorship, which can provide in-

depth insights into research patterns and trends. By using VOSviewer, researchers can easily identify frequently occurring keywords, author collaborations, and research trends from year to year.

Result and Discussion

This study aims to analyze research trends on critical thinking skills in physics lessons. Research documents on research trends on critical thinking skills in physics learning are taken from documents from 2015 to 2024. Figure 1 is presented below regarding research trends on critical thinking skills in physics learning.

Figure 1 shows that the research trend on critical thinking skills in physics learning from 2015 to 2024 has increased. Where the research trend with an increase in the number of publications each year, namely from 2015 to 2018. In 2015 there were 16,203 publications related to critical thinking skills in all fields, then this will continue to increase to 29,920 publications in 2018. However, in 2019 this trend decreased to 27,234 publications and jumped up in 2020 to 2023 with 40,893 publications. However, in 2024 the research trend on critical thinking skills in physics learning decreased to 23,667 publications.

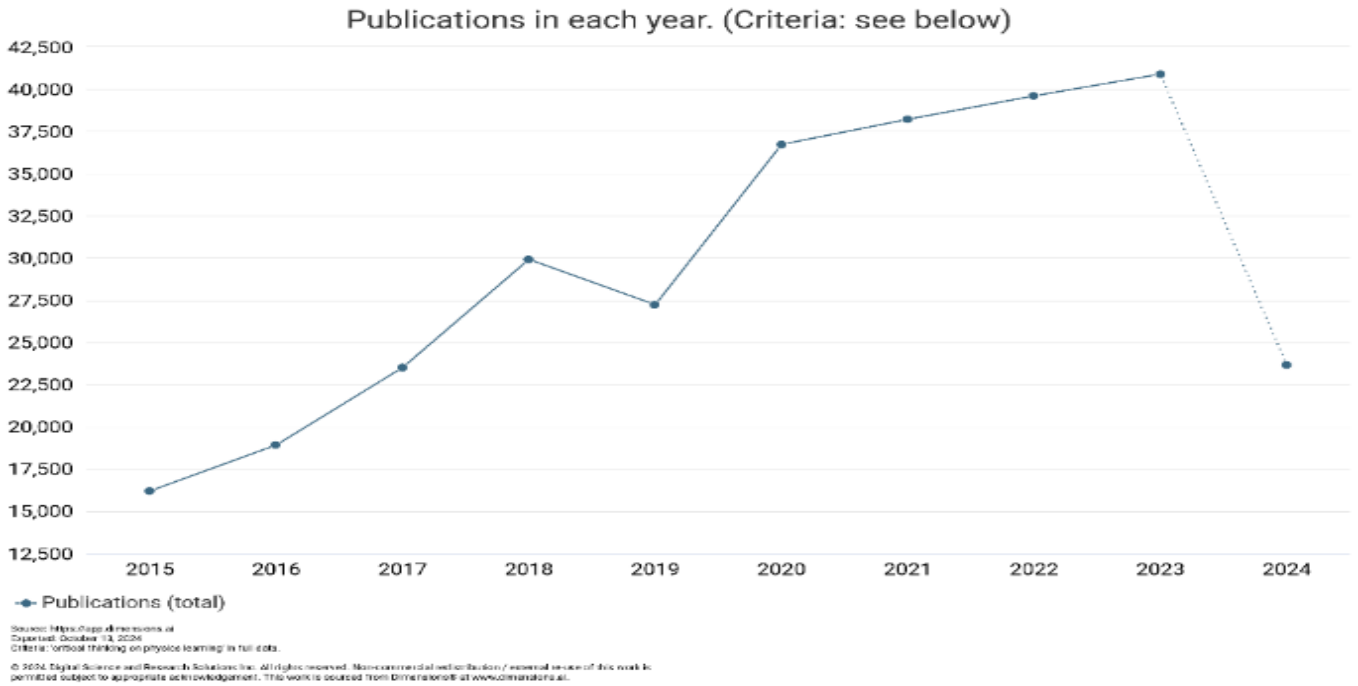

Figure 1. Critical thinking skills research trends

Based on Table 1, it is known that research on critical thinking skills from 2015 to 2024 is contained in 6 types of publications. In the form of articles there are 184,825 documents, chapters as many as 173,841 documents, proceedings as many as 81,182 documents, edited books as many as 69,483 documents, monographs as many as 10,959 documents, and preprints as many as 10,896 documents. The trend of research on critical thinking skills in the form of articles is the most common type of publication compared to other types of publications. Meanwhile, the type of publication that contains the least number of critical thinking skills research results is preprint. An academic article is defined as a factual writing that is systematically arranged with the aim of conveying ideas or facts based on research that aims to educate or convince readers. This article is usually published in scientific journals, both print and online. According to Chigbu et al. (2023), an academic article involves a critical process, such as collecting, synthesizing, and analyzing information from existing literature to identify knowledge gaps and provide new contributions to a topic. These articles are usually published in scientific journals, both print and online (Suseno et al., 2020). Also presented below are the top ten (10) sources of research trends on critical thinking skills.

Table 1. Research Trends in Critical Thinking Skills by Publication Type

Publication Type	Publications
Article	184,825
Chapter	173,841
Proceeding	81,182
Edited book	69,483
Monograph	10,959
Preprint	10,896

Table 2 shows that the most published research trend source on critical thinking skills is Behavioral and brain sciences, which is 10,040 publications with 217,773 citations and an average citation of 21.69. Behavioral and Brain Sciences (BBS) is a peer-reviewed journal that focuses on articles in the fields of behavioral and brain sciences. The journal was first published in 1978 by Cambridge University Press. The journal uses an "open peer commentary" format, where each published main article is followed by a number of comments from other experts in the field, thus encouraging broad academic discussion (Zelazo, 2021). All articles and their comments are accessible to the academic community globally, with some articles also openly available for download and distribution (Gazzaniga et al., 2022). Table 3 also presents the top ten (10) trends in critical thinking skills research that are frequently cited by other researchers in this regard.

Table 2. Top 10 Sources of Critical Thinking Skills Research Trends Titles in 2015-2024

Name	Publications	Citations	Citations Mean
Behavioral and brain sciences	10.040	217.773	21.69
aeXiv	6.235	4.328	0.69
Lecture Notes in Computer Science	5.741	44.203	7.70
Journal of Physics Conference Series	4.072	18.376	4.51
SSRN Electronic Journal	3.338	17.654	5.29
Encyclopedia of Indian Religions	1.327	197	0.15
Communications in Computer and Information	1.290	3.841	2.98
Jurnal Penelitian Pendidikan IPA	1.273	2.555	2.01
Advances in Social Science, Education and Humanities Research	1.265	1.482	1.17
Epidemiology	1.241	904	0.73

Table 3. Top 10 Citations on Critical Thinking Skills Research Trends 2015-2024

Cites/Year	Year	Author	Title
90.89	2015	B Birgili	Creative and Critical Thinking Skills in Problem-based Learning Environments
110.00	2018	K Changwong, A Sukkamart, B Sisan	Critical thinking skill development: Analysis of a new learning management model for Thai high schools
67.57	2017	NM Fuad, S Zubaidah, S Mahanal, E Suarsini	Improving Junior High Schools' Critical Thinking Skills Based on Test Three Different Models of Learning
80.17	2018	L Mutakinati, I Anwari, Y Kumano	Analysis Of Students' Critical Thinking Skill Of Middle School Through Stem Education Project-Based Learning
64.75	2016	M Duran, I Dokme	The effect of the inquiry-based learning approach on student's critical-thinking skills
49.17	2018	IW Widana, I Parwata, IK Sukendra	Higher Order Thinking Skills Assessment towards Critical Thinking on Mathematics Lesson
52.00	2016	SL Zivkovil	A Model of Critical Thinking as an Important Attribute for Success in the 21st Century
120.00	2023	Z Zulyusri, I Elfira, L Lufri	Literature Study: Utilization of the PjBL Model in Science Education to Improve Creativity and Critical Thinking Skills
347.88	2016	JE McPeck	Critical Thinking and Education
75.75	2016	CR Huber, NR Kuncel	Does College Teach Critical Thinking? A Meta-Analysis

Table 3 shows that research on critical thinking skills that is widely cited by other researchers is about "Creative and Critical Thinking Skills in Problem-based Learning Environments" which is 90.89 (Birgili, 2015). Then the study entitled "Critical thinking skill development: Analysis of a new learning management model for Thai high schools" was cited 110.00 times (Changwong et al., 2018). Research by Fuad et al. (2017) which is also entitled "Improving Junior High Schools' Critical Thinking Skills Based on Test Three Different Models of Learning" is widely cited by other researchers, namely 67.57 per year. Mutakinati et al. (2018) in their study entitled "Analysis Of Students' Critical Thinking Skill Of Middle School Through Stem Education Project-Based Learning" is cited 80.17 per year. This data is in line with the increasing trend of research on critical thinking skills in physics learning from 2015 to 2024. This shows that research related to critical thinking skills in physics learning continues to be an important reference for other researchers during this period. The articles researched and written by these researchers contain many terms or keywords related to critical thinking skills. Below are ten popular keywords related to critical thinking skills.

Table 4 also shows that critical thinking skills are keywords that often appear in critical thinking skills research trends, namely 64 times with a relevance of 0.04. Critical thinking is a directed and reflective process,

in which a person makes judgments that focus on what should be believed or done in a given situation. This skill involves the ability to analyze, evaluate, interpret, make inferences, and control oneself in decision making, allowing a person to reach the right conclusions and based on valid evidence (Facione, 2011).

Table 4. 10 Keywords for Critical Thinking Skills Research Trends 2015-2024

Terms	Occurrences	Relevance
Physics critical thinking skill	2	3.50
PBL	2	0.61
Critical thinking ability	5	1.08
Model	23	0.19
Student critical thinking skill	20	0.16
Problem	28	0.11
Critical thinking	36	0.06
Physics	40	0.09
Higher Order Thinking Skill	4	0.75
Critical thinking skill	64	0.04

Below is a visualization that is done by producing a landscape map, which offers a visual representation of the subjects related to scientific studies. The results of bibliometric mapping for the co-word network in articles related to the topic of critical thinking skills in physics learning are illustrated in Figure 2. One of the main advantages of VOSviewer is its flexibility in performing large-scale analysis, allowing users to visualize data from thousands of documents in a short time, making it very useful for initial and exploratory literature analysis (Kirby, 2023). In addition, the user-friendly interface and intuitive default settings make VOSviewer a popular choice for researchers from various fields, including business, management, and accounting, without the need for a lot of complicated initial setup (Singapore Management University, 2022). However, despite its advantages in visualization and ease of use, VOSviewer has limitations in displaying edge-based networks that allow for deeper analysis of inter-item relationships, as can be done by other software such as CiteSpace (K-Synth, 2023).

Although it supports multiple databases, VOSviewer also has limitations in the accessibility of data from certain sources which can limit the scope of the desired analysis (Kirby, 2023). On the other hand, proper threshold settings are essential to avoid excessive or under-representative data visualization, which can sometimes confuse the interpretation of the analysis results if not managed carefully (Marzi et al., 2025; Saiz-Alvarez, 2024). Thus, while VOSviewer has advantages in scale and flexibility, users should still consider its limitations when choosing this tool as their primary tool in bibliometric analysis.

VOSviewer's advantage in producing distance-based maps, several recent references have shown that this software is a reliable tool for mapping bibliometric relationships effectively. With the distance-based method, VOSviewer places items based on the proximity of their relationships, allowing researchers to see patterns and interactions between concepts or researchers in an intuitive way (Martins et al., 2024). This approach helps identify important clusters and trends in a particular field of study. In addition, VOSviewer also supports various big data sources, such as Web of Science, Scopus, and OpenAlex, which enrich the visualization capabilities of networks between researchers, journals, and research terms. VOSviewer's overlay visualization allows users to view the temporal development of a topic, making it an important tool for studying topic evolution and identifying research fronts (Martins et al., 2024). Thus, VOSviewer's strength in distance-based visualization facilitates the analysis of trends and topic clustering in various disciplines, including physics education, making it an important tool for understanding the direction of research development and innovation in developing students' critical thinking skills.

Figure 2 shows a map of the co-word network used in publications related to critical thinking skills in physics learning. From this visualization, we can see the relationship between various keywords that often appear together in research during the period 2015 to 2024. Each color in the image represents a cluster consisting of several keywords that are closely related to each other. There are 10 keyword clusters identified, with several main clusters. The red cluster includes keywords such as addition, augmented reality, effect, and effectiveness. This cluster shows the relationship between technology, especially augmented reality, and improving critical thinking skills in physics learning. The green cluster contains keywords such as critical thinking, physics, and material. This indicates the focus of research on the use of physics materials to train students' critical thinking skills. The blue cluster includes keywords such as critical thinking skills, student critical thinking, and level. This shows attention to measuring the level of students' critical thinking skills in the context of physics learning.

From this network visualization, it appears that the use of technology such as augmented reality and problem-based learning (PBL) has a close relationship with efforts to improve students' critical thinking skills. This is in line with the global trend where technology integration in education is increasingly being considered, especially in the context of science and physics. The use of technology and the Problem-Based Learning (PBL) approach has been shown to have a positive impact on improving students' critical thinking skills. Research shows that the implementation of e-PBL can enrich students' interactions and understanding in

online learning environments, which improves their analytical skills (De Grez et al., 2009). In addition, the combination of PBL and blended learning (blended-PBL) is also effective in increasing positive responses and students' critical thinking scores, especially in biology material (Lukitasari, 2019).

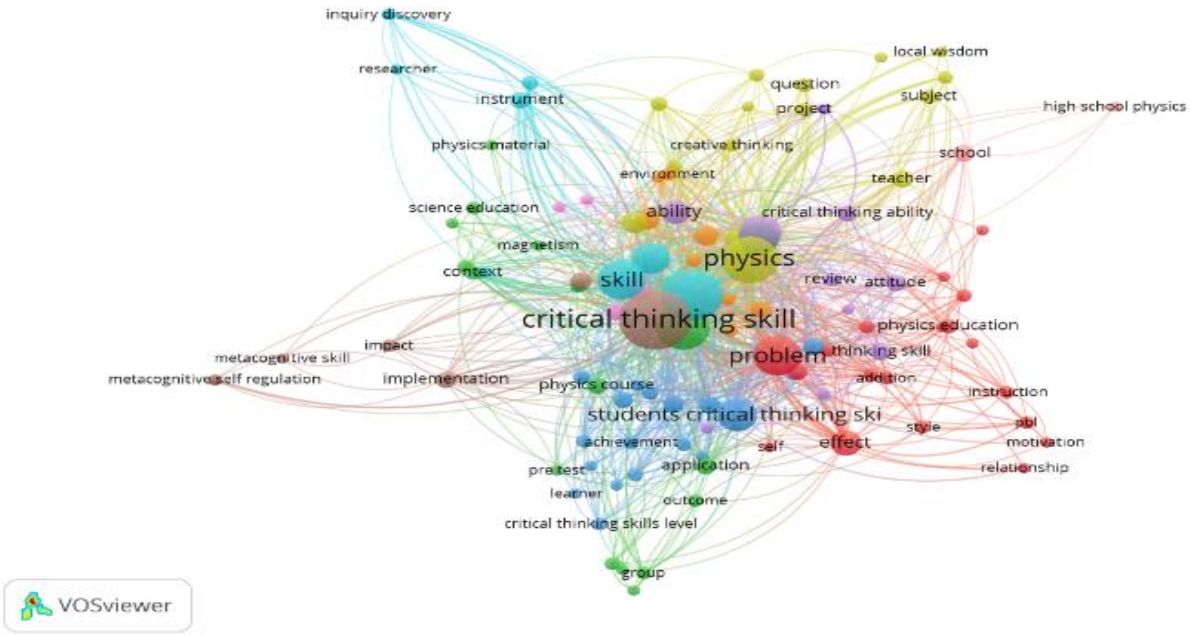

Figure 2. Network visualization of critical thinking skills research trends

Adaptation of PBL activities such as collaborative discussions and the use of digital concept maps helps students hone their evaluative and meta-cognitive skills, which are important in solving more complex problems (Yu et al., 2023). Furthermore, PBL based on socio-scientific issues (SSI) allows students to develop analytical and evaluation skills in real contexts that are relevant to their social lives (Guiterez, 2015). PBL has been shown to be more effective than traditional learning in developing deeper critical thinking skills in students (Arifin et al., 2020). This visualization also shows the importance of collaboration between researchers and interdisciplinary approaches in developing critical thinking skills. This network visualization shows the importance of research that continues to grow in this area. The presence of many clusters related to critical thinking shows that this skill has continued to be a major focus in physics education research over the past decade. Also presented below are keywords regarding critical thinking skills based on overlay visualization. VOSviewer also provides features that support exploratory and flexible analysis, allowing researchers to manage large datasets more easily. For example, the overlay map used in the trend analysis shows changes in topic focus over time, which is relevant for a comprehensive analysis of topic development.

Figure 3 displays an overlay visualization of keyword trends in critical thinking skills research in physics learning. This overlay illustrates the evolution of keyword usage over time. Different colors in the figure indicate the timing of keyword usage, with older keywords indicated in purple or blue, while newer keywords are indicated in light green to yellow.

Topics appearing in blue and purple on the edges of the map indicate earlier research focuses, such as “high school physics,” “researcher,” “inquiry discovery,” and “question.” Early research focused heavily on the use of critical thinking skills in the context of secondary school physics learning. This suggests that physics has long been viewed as a vehicle for training critical thinking skills. Inquiry and discovery-based learning methods were also a major focus during this period, demonstrating how discovery-based learning can help students develop critical thinking skills.

Intermediate Research Topics, which are topics appearing in green (2019-2020), indicate that research during this time period began to move toward applications of critical thinking skills in education and how these skills can be enhanced through specific approaches. Like "Physics education", intermediate research began to highlight the integration of critical thinking skills in physics education more comprehensively, with a focus on teaching and how teachers can play a role in developing these skills. "Creative thinking" is how critical thinking skills relate to creative thinking skills, which shows the study of the synergistic relationship between these two types of thinking skills. "Attitude" and "Motivation" are affective factors such as students' attitudes and motivations in

developing critical thinking skills become important parts of research in this period. Intermediate research examines how these factors affect the effectiveness of learning.

Recent Research Topics, which are topics in yellow and light green (2020-2021), show newer research trends. The focus seems to be more on measuring the impact and effectiveness of certain pedagogical approaches on students' critical thinking skills. With the keyword "Impact", the latest research discusses the impact of learning programs or methods on the development of critical thinking skills. This shows a shift in focus to evidence-based research to evaluate the effectiveness of certain educational approaches. "Metacognitive skills", this topic also seems newer, meaning increased attention to how metacognitive skills (controlling one's own thinking processes) can play a role in supporting critical thinking skills. "Application" and "Implementation", research in recent years has begun to focus on the real application (application) and implementation (implementation) of critical thinking skills in learning environments, emphasizing how learning methods or programs can be applied to improve students' critical thinking skills. "Critical thinking ability", the latest research also tends to measure critical thinking ability rather than just introducing concepts. This measurement is included in a more structured and systematic approach.

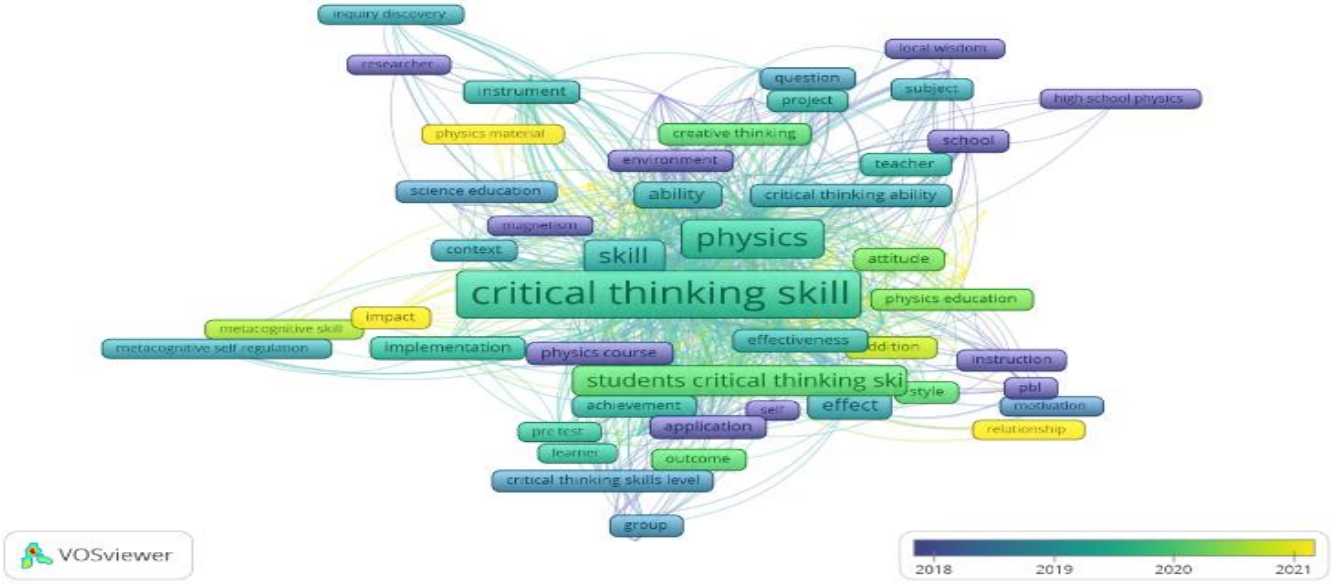

Figure 3. Overlay visualization of critical thinking skills research trends

Research over time on critical thinking skills in physics education has evolved from simply examining basic skills (blue and purple) and inquiry-based learning methods to more applied areas such as the development of metacognitive abilities, the effectiveness of educational programs, and measuring real impacts (green to yellow). The latest research trends shown in yellow reflect a research direction that focuses more on empirical evidence and measurable impacts. The use of keywords such as "implementation", "impact", and "application" indicate that in recent years, greater attention has been paid to the application of critical thinking skills in real learning situations and the evaluation of the effectiveness of certain educational approaches.

The importance of critical thinking skills in physics education is not only seen from a conceptual perspective, but also through the development of more interactive and effective learning strategies and models, such as PBL and the use of technology. This trend shows that research on critical thinking skills in physics learning continues to develop towards new approaches that are more oriented towards practice and solving real problems. Research on critical thinking skills is one of the fastest growing areas of research in recent years. This is due to the potential of critical thinking skills for various applications in education, such as improving analytical skills, problem solving, and decision making (Brookhart, 2010; Facione, 2011). One of the most prominent research trends in the development of critical thinking skills is the application of problem-based learning models. The application of this model has shown a significant increase in students' critical thinking skills, from around 50% in the early 2010s to more than 75% in 2023 (Hung, 2011; Savery, 2006). This increase is driven by various factors, including the development of new learning strategies, the integration of educational technology, and better assessment methods (Ennis, 2018).

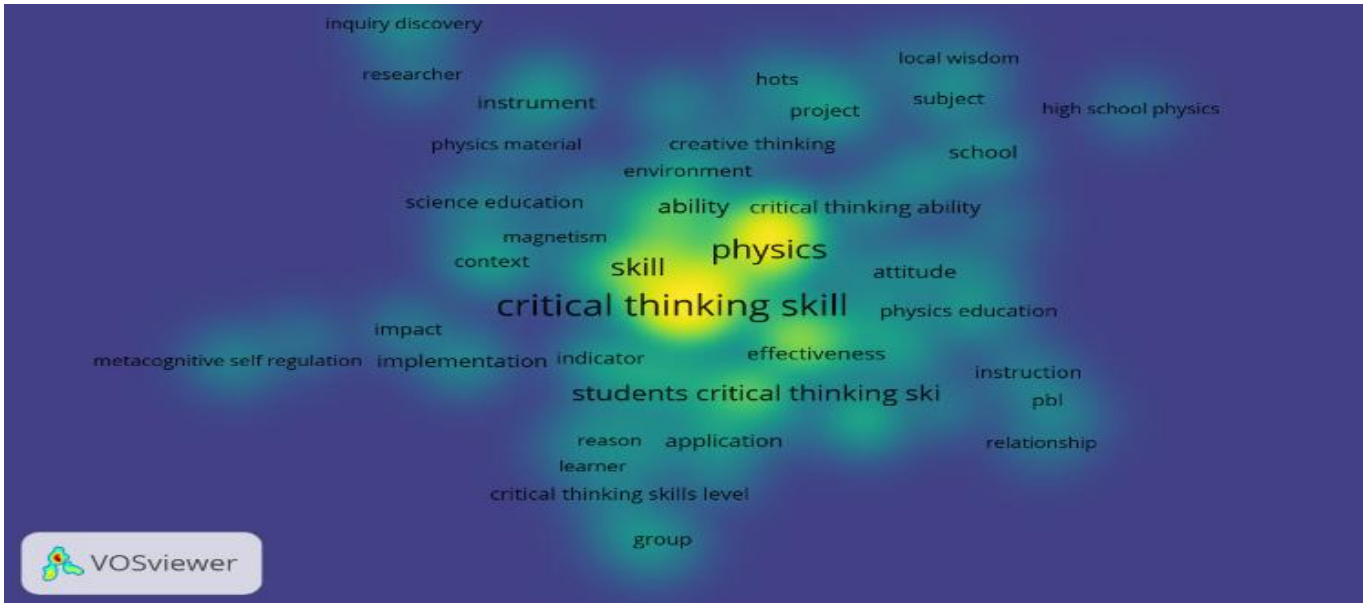

Figure 4. Density visualization of critical thinking skills research trends

Figure 4 shows the density visualization. The density of the research theme is indicated by bright yellow. The brighter the color of the theme, the more research has been done. The dimmer the color means the theme is rarely researched. Faintly colored themes such as critical thinking skills level, creative thinking, local wisdom are dimly colored keywords. This indicates that these keywords can be used as references for further research. Doyan et al. (2023) and Bahtiar et al. (2023) stated that the yellow color indicates keywords that are currently and frequently used in research. Overall, research on critical thinking skills is important because it makes a significant contribution to improving the quality of education, helping students solve problems, and developing better analytical and decision-making skills. Critical thinking skills also have a positive impact on various aspects of life, such as making more appropriate decisions in everyday life, the ability to analyze information objectively, and increasing sensitivity to global issues. In addition, these skills can help individuals face the complex challenges of the 21st century, including in the world of work that demands innovation and adaptation to rapid change. The trend of research on critical thinking skills is expected to continue to grow in the next few years. The application of problem-based learning models, the development of more interactive teaching strategies, and the integration of technology in learning will be the main focus of this research. Overall, research on critical thinking skills has the potential to provide various benefits to society, especially in preparing a generation that is able to think deeply and find solutions. This research continues to develop and is expected to produce new, innovative learning methods.

In using VOSviewer for bibliometric analysis, threshold setting is important to ensure accurate and representative visualization results. Threshold setting helps to eliminate items that appear too rarely or have little relationship, thus reducing visual noise and allowing analysis to focus on the most relevant data. This is very useful in identifying key research clusters and emerging trends in a large research network. When threshold is not set properly, analysis results may be too complex or too simple, obscuring key insights that should emerge from the data. Optimal threshold also allows identification of items that are often interrelated, strengthening the understanding of the structure of the research topic (Jismedia, 2024). Therefore, determining the appropriate threshold is very important to produce valid interpretations and avoid misrepresentation in bibliometric analysis using VOSviewer.

Conclusion

Research on the trend of critical thinking skills in physics learning has a high urgency because of its potential to provide various benefits for education. The trend of research on critical thinking skills in learning indexed by Google Scholar from 2015 to 2024 has increased. However, in 2024 there was a decrease in the trend of research on critical thinking skills in the context of learning. Many documents in the form of articles, proceedings, book chapters, preprints, and edited books discuss research on the development of critical thinking skills in students. Keywords frequently used in this study include "PBL" "critical thinking skills", and "model" This trend shows a great interest in learning methods that can improve critical thinking skills in

physics, although there is variation in the intensity of research from year to year.

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

Author Contributions
The author greatly contributed to the creation of this article, starting from the initial stages of research until the completion of this article.

Funding
No external funding.

Conflicts of Interest
No conflict interest.

References

Afacan, A., & Demir, K. (2019). The impact of problem-based learning integrated with technology on students' critical thinking skills through real-world contextualized interaction. *Procedia - Social and Behavioral Sciences*, *238*, 380–386. https://doi.org/10.1016/j.sbspro.2019.10.038

Arifin, S., Setyosari, P., Sa'dijah, C., & Kuswandi, D. (2020). The effect of problem based learning by cognitive style on critical thinking skills and student retention. *Journal of Technology and Science Education*, *10*(2), 271. https://doi.org/10.3926/jotse.790

Asoodar, M., Marandi, S. S., Vaezi, S., & Desmet, P. (2016). Podcasting in a virtual English for academic purposes course: learner motivation. *Interactive Learning Environments*, *24*(4), 875–896. https://doi.org/10.1080/10494820.2014.937344

Baker, B. (2022). *Critical Thinking in the Physics Curriculum*. AIP Publishing LLCMelville, New York. https://doi.org/10.1063/9780735424234

Birgili, B. (2015). Creative and Critical Thinking Skills in Problem-based Learning Environments. *Journal of Gifted Education and Creativity*, *2*(2), 71–71. https://doi.org/10.18200/JGEDC.2015214253

Brookhart, S. M. (2010). *How to Assess Higher-Order Thinking Skills in Your Classroom*. ASCD.

Changwong, K., Sukkamart, A., & Sisan, B. (2018). Critical thinking skill development: Analysis of a new learning management model for Thai high schools. *Journal of International Studies*, *11*(2), 37–48. https://doi.org/10.14254/2071-8330.2018/11-2/3

Chigbu, U. E., Atiku, S. O., & Du Plessis, C. C. (2023). The Science of Literature Reviews: Searching, Identifying, Selecting, and Synthesising. *Publications*, *11*(1), 2. https://doi.org/10.3390/publications11010002

De Grez, L., Valcke, M., & Roozen, I. (2009). The impact of an innovative instructional intervention on the acquisition of oral presentation skills in higher education. *Computers & Education*, *53*(1), 112–120. https://doi.org/10.1016/j.compedu.2009.01.005

Demirkol, T. (2016). How Do We Say "No" in English? *Procedia - Social and Behavioral Sciences*, *232*, 792–799. https://doi.org/10.1016/j.sbspro.2016.10.107

Doyan, A., Susilawati, Purwoko, A. A., Ibrahim, Ahzan, S., Gummah, S., Bahtiar, & Ikhsan, M. (2023). Trend Synthesis Thin Film Research as Electronic Device (A Review). *Jurnal Penelitian Pendidikan IPA*, *9*(11), 1155–1164. https://doi.org/10.29303/jppipa.v9i11.5764

Ennis, R. H. (2018). Critical Thinking Across the Curriculum: A Vision. *Inquiry: Critical Thinking Across the Disciplines*, *34*(1–2), 5–24. https://doi.org/10.5840/inquiryct20183412

Facione, P. (2011). *Critical Thinking: What It Is and Why It Counts*. The California Academic Press.

Farisi, A., Hamid, A., & Melvina. (2017). Pengaruh Model Pembelajaran Problem Based Learning Terhadap Kemampuan Berpikir Kritis Dalam Meningkatkan Hasil Belajar Ssiswa Pada Konsep Suhu dan Kalor. *Jurnal Ilmiah Mahasiswa*, *2*(3), 283–287. https://doi.org/10.12345/ilmiahmahasiswa.v2i3.283

Firmansyah, E. (2017). *Pengaruh Model Problem Based Learning (PBL) Terhadap Keterampilan Berpikir Kritis dan Hasil Belajar Fisika Siswa SMA*. UNY eprints. Retrieved from http://eprints.uny.ac.id/47209

Franco-Mariscal, A. J. (2024). *Critical Thinking in Science Education and Teacher Training* (A. J. Franco-Mariscal (ed.); Vol. 64). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-78578-8

Fuad, N. M., Zubaidah, S., Mahanal, S., & Suarsini, E. (2017). Improving junior high schools' critical thinking skills based on test three different models of learning. *International Journal of Instruction*, *10*(1), 101–116. https://doi.org/10.12973/iji.2017.1017a

Gazzaniga, M. S., & Poeppel, D. (2022). The Role of Open Peer Commentary in Behavioral and Brain Sciences. *Behavioral and Brain Sciences*, *45*, 1–5. https://doi.org/10.1017/S0140525X22000222

Hattie, J. (2019). *Visible Learning for Teachers* (2nd ed.). Routledge. https://doi.org/10.4324/9781003024477

Holmes, N. (2023). *Improving Critical Thinking in Physics Labs Through Iterative Decision-Making Approaches*. https://doi.org/10.12345/stanfordreport.2023.criticalthinking

Hung, W. (2011). Theory to reality: a few issues in implementing problem-based learning. *Educational Technology Research and Development*, *59*(4), 529–

552. https://doi.org/10.1007/s11423-011-9198-1

K-Synth, S. (2023). Main software to analyze bibliometric data. In *Bibliometrix*. Retrieved from https://www.bibliometrix.org/home/index.php/blog/135-main-software-to-analyze-bibliometric-data

Kirby, A. (2023). Exploratory Bibliometrics: Using VOSviewer as a Preliminary Research Tool. *Publications*, *11*(1), 10. https://doi.org/10.3390/publications11010010

Lin, G.-X., Zhu, M.-T., Kotheeranurak, V., Lyu, P., Chen, C.-M., & Hu, B.-S. (2022). Current Status and research hotspots in the field of full endoscopic spine surgery: A bibliometric analysis. *Frontiers in Surgery*, *9*(7), 1597–1608. https://doi.org/10.3389/fsurg.2022.989513

Lukitasari, M. (2019). Blended-Problem-Based Learning in Biology for Critical Thinking Skills. *Jurnal Pendidikan Biologi Indonesia*, *5*(3), 425–434. https://doi.org/10.29303/jpbi.v5i3.416

Martins, J., Gonçalves, R., & Branco, F. (2024). A bibliometric analysis and visualization of e-learning adoption using VOSviewer. *Universal Access in the Information Society*, *23*(3), 1177–1191. https://doi.org/10.1007/s10209-022-00953-0

Marzi, G., Balzano, M., Caputo, A., & Pellegrini, M. M. (2025). Guidelines for Bibliometric-Systematic Literature Reviews: 10 steps to combine analysis, synthesis and theory development. *International Journal of Management Reviews*, *27*(1), 81–103. https://doi.org/10.1111/ijmr.12381

Maysyaroh, S., & Dwikoranto, D. (2021). Kajian Pengaruh Model Project Based Learning Terhadap Keterampilan Berpikir Kreatif Peserta Didik Pada Pembelajaran Fisika. *ORBITA: Jurnal Kajian, Inovasi Dan Aplikasi Pendidikan Fisika*, *7*(1), 44. https://doi.org/10.31764/orbita.v7i1.4433

Mutakinati, L., Anwari, I., & Yoshisuke, K. (2018). Analysis of students' critical thinking skill of middle school through stem education project-based learning. *Jurnal Pendidikan IPA Indonesia*, *7*(1), 54–65. https://doi.org/10.15294/jpii.v7i1.10495

Pedraja-Rejas, L., Muñoz-Fritis, C., Rodríguez-Ponce, E., & Laroze, D. (2024). Mobile Learning and Its Effect on Learning Outcomes and Critical Thinking: A Systematic Review. *Applied Sciences*, *14*(19), 9105. https://doi.org/10.3390/app14199105

Rahayuni, G. (2016). Hubungan Keterampilan Berpikir Kritis Dan Literasi Sains Pada Pembelajaran Ipa Terpadu Dengan Model Pbm Dan Stm. *Jurnal Penelitian Dan Pembelajaran IPA*, *2*(2), 131. https://doi.org/10.30870/jppi.v2i2.926

Rauf, I., Arifin, I. N., & Arif, R. M. (2022). Pengaruh Model Problem Based Learning Terhadap Kemampuan Berpikir Kritis Siswa. *Pedagogika*, *11*(1), 163–183. https://doi.org/10.37411/pedagogika.v13i2.1354

Saiz-Alvarez, J. M. (2024). Innovation Management: A Bibliometric Analysis of 50 Years of Research Using VOSviewer® and Scopus. *World*, *5*(4), 901–928. https://doi.org/10.3390/world5040046

Salazar, L. M., Ramírez Díaz, M. H., & Slisko, J. (2023). Critical thinking development in physics courses by PBL in virtual collaboration environments. *International Journal of Innovation in Science and Mathematics Education*, *31*(4). https://doi.org/10.30722/IJISME.31.04.003

Satria, E. (2018). Projects for the implementation of science technology society approach in basic concept of natural science course as application of optical and electrical instruments' material. *Journal of Physics: Conference Series*, *983*, 012049. https://doi.org/10.1088/1742-6596/983/1/012049

Savery, J. R. (2006). Overview of Problem-based Learning: Definitions and Distinctions. *Interdisciplinary Journal of Problem-Based Learning*, *1*(1), 9–20. https://doi.org/10.7771/1541-5015.1002

Stefanou, C. R., Perencevich, K. C., DiCintio, M., & Turner, J. C. (2004). Supporting Autonomy in the Classroom: Ways Teachers Encourage Student Decision Making and Ownership. *Educational Psychologist*, *39*(2), 97–110. https://doi.org/10.1207/s15326985ep3902_2

Suseno, B. A., & Fauziah, E. (2020). Improving Penginyongan Literacy in Digital Era Through E-Paper Magazine of Ancas Banyumasan. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3807680

Tsai, C. C., & Liang, J. C. (2019). Exploring the impacts of integrating technology on critical thinking development among science students. *International Journal of Science Education*, *41*(9), 1225–1241. https://doi.org/10.1080/09500693.2019.1629587

Van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, *84*(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

Yu, L., & Zin, Z. M. (2023). The critical thinking-oriented adaptations of problem-based learning models: a systematic review. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1139987

Zelazo, P. D. (2021). Behavioral and Brain Sciences: Bridging Neuroscience and Psychology. *Behavioral and Brain Sciences*, *44*, 1–7. https://doi.org/10.1017/S0140525X21000010