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Artikel

Bibliometric Analysis: The Role of Augmented Reality in Transforming Science Learning to Improve Students' Critical Thinking Skills

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Info Artikel

1st AVES
Annual Virtual Conference of
Education and Science 2025

Kata kunci:

Bibliometric,
Augmented Reality,
Critical Thinking,
Science Learning

ABSTRACT

Augmented Reality is used in learning because it is interactive and can visualize real material in the form of displays. Augmented Reality is one of the technologies that helps students develop critical thinking skills. Critical thinking skills are important to develop in students, especially in science learning because it is one of the 21st-century skills that students must have to face challenges in real life. The study aims to identify scientific publications related to Augmented Reality (AR), critical thinking skills, and science learning. The research method is a literature study through bibliometric analysis using the Publish or Perish application, Microsoft Excel, and VOS Viewer. The research subjects are scientific articles published in journals indexed by Scopus, Crossref, and Google Scholar. The results of the scientific journal search were then mapped and percentaged to determine research trends. The percentage results were then analyzed descriptively qualitatively. The results show that scientific publications with keywords Augmented Reality, critical thinking skills, and science learning have a tendency to increase; 2) The highest percentages were in 2021, 2023, and 2024, namely 12%, 12.7%, and 17.2%, and the lowest were in 2016, 2017, and 2018, namely 3.5%, 5.8%, and 5.8%; 3) The increase in research trends was less than 50%. The increase in trends contributes to more in-depth research on Augmented Reality in developing critical thinking skills in science learning.

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PENDAHULUAN

Scientific publications are a means for researchers to access and disseminate knowledge and evaluate research quality, allowing for global scientific publication trends to be analyzed (Dodds, 2019). Trends in scientific publications on Augmented Reality, critical thinking skills, and science learning can be openly accessed and analyzed using bibliometric methods (Greshake, 2017); (Zhu & Liu, 2020). Bibliometrics is a popular and rigorous method for exploring and analyzing large amounts of scientific data and allows for highlighting topics under study, resulting in significant research impact (Donthu et al., 2021). A sound bibliometric analysis can build a solid foundation for advancing a field in new and meaningful ways (Ellegaard, 2018). Bibliometric analysis allows for a comprehensive

overview, identifying knowledge gaps, and generating new research ideas, particularly regarding Augmented Reality, critical thinking skills, and science learning (Tran et al., 2019); (Donthu et al., 2021).

Augmented Reality (AR) is a technology that combines digital objects into the real world interactively, which has revolutionized various fields, one of which is education. Augmented Reality in education can be implemented in learning, not only increasing student engagement but also deepening conceptual understanding through concrete three-dimensional visualization experiences (Mustaqim et al., 2025). Augmented Reality simulated in various learning tasks has been shown to improve knowledge retention and practical skills (Çukurbaşı, 2025). Augmented Reality supports personalized learning, allowing students to learn at a pace and style that suits their preferences (Kovalchuk, 2025). Augmented Reality is attractive in learning because students can interact naturally with events and objects (Jdaitawi et al., 2022). Augmented Reality can be implemented in science learning such as visualizing the structure of the human body, the molecular structure of a substance, and the structure of the solar system (Cipresso et al., 2018); Davila Delgado et al., 2020; Arena et al., 2022).

Augmented Reality in science learning enables the implementation of “virtual field trips” that expand the learning experience without geographical barriers (Fotiadis et al., 2025). The integration of Augmented Reality in science learning provides interactive visual representations that enable direct and realistic exploration of scientific phenomena. Augmented Reality in science learning has brought significant changes in the way students understand abstract concepts; increased motivation and in-depth understanding of molecular concepts; and mapped the structure of cells and tissues, making topics more interesting and easier to understand (Tran et al., 2019; Hasminar Rachman Fidiastuti, Sri Rahayu Lestari, Suhadi, 2025). Augmented Reality in science learning can facilitate a combination of learning environments that can improve critical thinking skills, including students using physical and digital materials in one environment (Ozdemir et al., 2018).

A study by Samaniego López & Orrego Riofrío (2025) confirmed that the use of Augmented Reality in inclusive education can increase active participation and the development of critical thinking skills needed in the 21st century in addition to problem solving and analytical thinking (Karenina et al., 2020; Nafi Mamluah et al., 2023). Augmented Reality can improve students' critical thinking skills because it is able to provide a visual representation of the subject matter, making it easier for students to understand the material conceptually and practically (Badriyah et al., 2023). Augmented Reality supports the interpretation process by increasing students' curiosity, thus stimulating students to ask questions in learning (Zuniari et al., 2022). Augmented Reality implemented in student worksheets can be in the form of animated objects or videos that can help students discover and analyze concepts and support an independent learning environment, thereby shaping students' thinking processes (Herliandry et al., 2021; Zuniari et al., 2022). The results of the study (Faridi, 2020) show that the use of Augmented Reality (AR) in science learning significantly improves students' critical thinking skills. AR teaching group is 15.70 compared to the posttest score of the conventional teaching group is 12.15, which suggests that AR intervention has a significant positive impact on the learning gain of engineering students. Using.

Bibliometric analysis of the role of Augmented Reality in transforming science learning to improve students' critical thinking skills can provide a real contribution to educators and researchers because the direction of research development can be determined through visualization based on differences in cluster and overlay colors (Agus, 2024; Ahmet, 2024; Georgios, 2025). This study provides an overview of research trends through the percentage of scientific publications regarding dominant keywords so that it can identify the conceptual bridge between Augmented Reality, students' critical thinking skills, and science learning

(Aris, 2024). This research is a pedagogical transformation because Augmented Reality technology can improve students' skills in exploring and solving problems, especially in science learning (Risma, 2023). How is the bibliometric analysis of the role of Augmented Reality in transforming science learning to improve students' critical thinking skills?

METHOD

This qualitative research was analyzed using bibliometrics with 1,000 samples of scientific articles from the Scopus, Google Scholar, and Crossref databases using the Publish or Perish 8 application (Muntiari, 2024). Bibliometric analysis was used to identify factors of interest, namely Augmented Reality, critical thinking skills, and science learning (Roig-Tierno et al., 2017). The article search on June 17, 2025, used the keywords Augmented Reality, critical thinking skills, and science learning for the period 2015-2025. The search results were then mapped according to the year of publication and the relevance of the keywords: Augmented Reality, critical thinking skills, and science learning (Deda, 2023). The mapping results were calculated by dividing the number of each year by the number of scientific articles and multiplying by 100% to determine the percentage. The percentage results were analyzed descriptively.

Next, the sample scientific articles were mapped using the VosViewer application to visualize collaboration networks, article co-citation networks, and keyword co-occurrences (Ji et al., 2018). Color-based visualization was used to identify trends in scientific publications, while overlay-based visualization was used to determine the freshness of keywords used in research on Augmented Reality, critical thinking skills, and science learning. The visualization results using the VosViewer application were analyzed descriptively.

RESULT AND DISCUSSION

The results of the bibliometric analysis of keywords Augmented Reality, critical thinking skills, and science learning in 2015-2025 are shown in Table 1; Figures 1, 2, 3, and 4.

Table 1. Results of the percentage of searches for the keyword Augmented Reality, Critical Thinking Skills, and Science Learning in 2015-2025

No.	Year	Percentage
1	2015	6,80%
2	2016	3,50%
3	2017	5,80%
4	2018	5,80%
5	2019	10,70%
6	2020	9,30%
7	2021	12%
8	2022	7,9%
9	2023	12,7%
10	2024	17,2%
11	2025	8,3%

The percentage of scientific publications using the keywords "Augmented Reality," "Critical Thinking Skills," and "Science Learning" based on Figure 1 shows that the number of scientific articles published in 2015 was 6.8%; in 2016 it was 3.5%; in 2017 and 2018 it was 5.8%; in 2019 it was 10.7%; in 2020 it was 9.3%; in 2021 it was 12%; in 2022 it was 7.9%; in 2023 it was 12.7%; in 2024 it was 17.2%; and in 2025 it was 8.3%. The research results can be seen in the percentage increase in Figure 1.

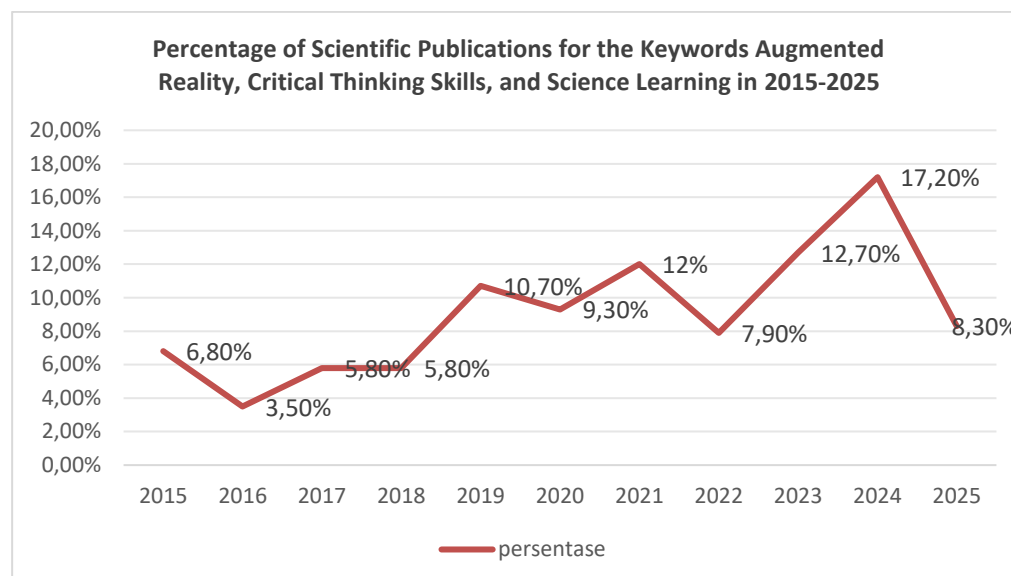


Figure 1. Percentage of Scientific Publications Using the Keywords "Augmented Reality, Critical Thinking Skills, and Science Learning" 2015-2025

In general, keywords regarding Augmented Reality, critical thinking skills, and science learning have the highest percentages in 2021, 2023, and 2024 at 12%; 12.7%; and 17.2%, respectively; while the lowest percentages are in 2016, 2017, and 2018 at 3.5%; 5.8%; and 5.8%. In general, the results of scientific publications regarding the keywords Augmented Reality, critical thinking skills, and science learning have a tendency to increase during 2015-2025. In 2025, the number of publications decreased because the results were only obtained until June. Publication trends can be visualized bibliometrically based on the differences in cluster colors in VosViewer as shown in Figure 2.

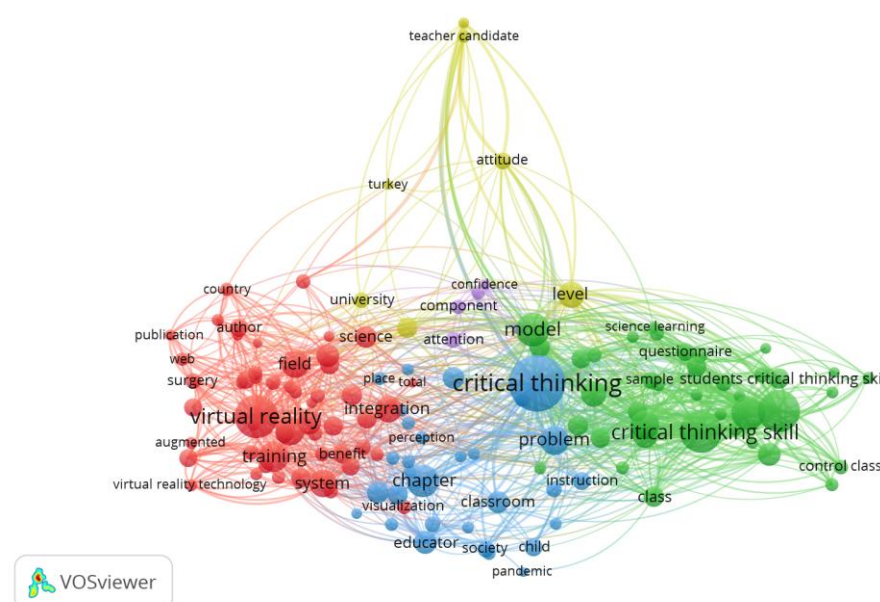


Figure 2. Bibliometric Visualization Based on Cluster Color Differences in VosViewer

Figure 2 shows a bibliometric visualization based on cluster color differences in Vos Viewer, which consists of five cluster colors: red, blue, green, yellow, and purple. The most frequently occurring keywords in each cluster are indicated by the largest circle size. The most frequently occurring keywords in the red, blue, green, yellow, and purple clusters are

virtual reality, critical thinking skills, critical thinking skills, level, and attention. The five cluster colors indicate a relationship, as evidenced by the connecting lines. In addition to the differences in cluster color, there are also differences in the years of scientific publication, as shown in Figure 3.

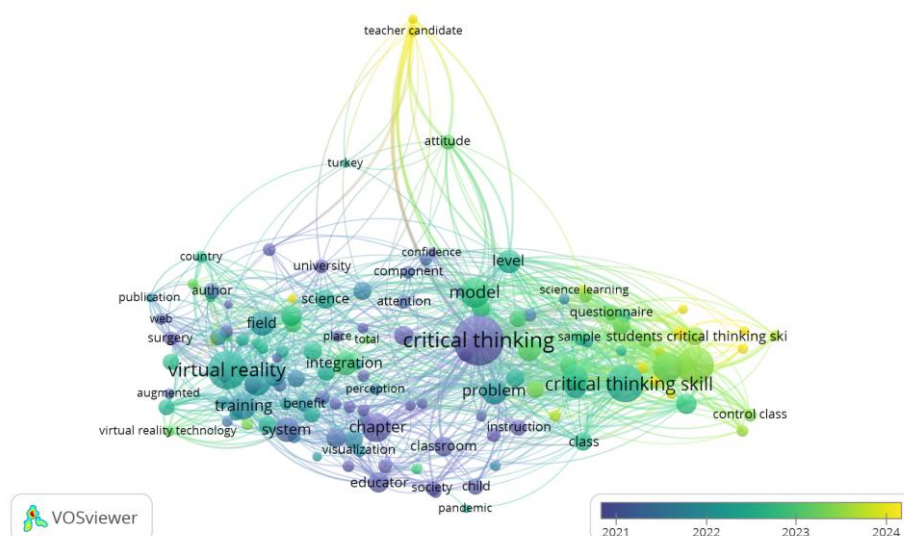


Figure 3. Bibliometrics Based on Differences in Overlay Colors in the Vos Viewer

The differences in overlay colors in the Vos Viewer, as seen in Figure 3, indicate the recency of the research. The brighter the color, the more recent the keywords used in the research. Based on Figure 3, three recent and interesting keywords can be identified: Augmented Reality, critical thinking skills, and science education. The relationship between the keywords Augmented Reality, critical thinking skills, and science education can be seen in Figure 4.

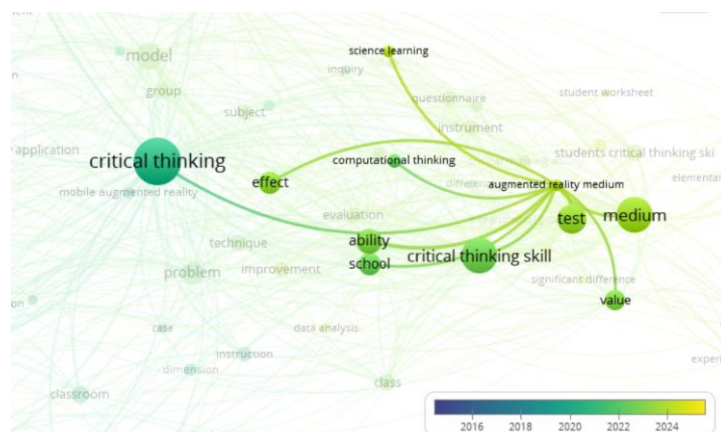


Figure 4. Visualization of the Emergence of Keywords: Augmented Reality, Critical Thinking Skills, and Science Learning

Figure 3 shows a visualization of the emergence of keywords: Augmented Reality, critical thinking skills, and science learning, which appear to be interconnected. The relationship between Augmented Reality, critical thinking skills, and science learning is evidenced by the connecting lines between them. The keywords: Augmented Reality, critical thinking skills, and science learning are the newest keywords, as indicated by the greenish-yellow color. The size of the circles indicates the number of research trends for each keyword; the larger the circle, the greater the number of studies related to the keyword. The circles for the keywords: Augmented Reality and science education are smaller than those for

the keyword: critical thinking skills. In general, the keywords: Augmented Reality, critical thinking skills, and science learning have the latest scientific publication trends, but they are still relatively low, requiring further, in-depth research.

Based on the bibliometric study of keywords Augmented Reality, critical thinking skills, and science learning, it can be seen that. The highest percentages were in 2021, 2023, and 2024, while the lowest were in 2016, 2017, and 2018. The publication trend of keywords Augmented Reality, critical thinking skills, and science learning has an increasing tendency during 2015-2025. The visualization of keywords Augmented Reality, critical thinking skills, and science learning appears to be interconnected and includes the latest research, but the number of scientific publications is still relatively low.

Augmented Reality is a technology that combines virtual information with the real world generated by computers, laptops, and portable devices, such as text, images, 3D models, music, videos, and animations, either separately or simultaneously (Chen et al., 2019). Augmented Reality can be used as a supporting technology for the teaching and learning process because it provides a unique learning experience that cannot be achieved with other technologies, such as in science learning, as it can explain abstract content (Avila-Garzon et al., 2021; Jiang et al., 2025)

Critical thinking skills are logical attitudes and skills in problem-solving contexts that produce interpretations, analyses, evaluations, and conclusions in accordance with science learning (García-carmona, 2025). Critical thinking skills are high-level cognitive skills that must be mastered in the 21st century because they help improve students' functioning in various situations, including analyzing problems, assessing and evaluating, and solving problems. and make decisions to solve problems that are in accordance with science learning (Widana, 2018; Basri et al., 2019; Saputra et al., 2019; Behar-Horenstein & Niu, 2011). v (Jdaitawi et al., 2022).

The high number of keywords for Augmented Reality, critical thinking skills, and science learning in 2021, 2023, and 2024 indicates that the research trend regarding Augmented Reality, critical thinking skills, and science learning continues to increase. This research trend is increasing because learning methods are increasingly digitalized and driven by technological innovation, addressing learning content related to affordability and accessibility, thus providing a reality solution as a teaching and learning tool that can increase engagement and interactivity (Kim et al., 2018; Kamińska et al., 2023). The increasing research trend indicates researchers' interest in the keywords, for example, a large number of scientific articles focus on how game-based learning strategies can be combined with Augmented Reality learning experiences (Eric Klopfer, 2019). The increasing research trend for the keywords Augmented Reality, critical thinking skills, and science learning is due to their ability to effectively stimulate interest and improve achievement and motivation in science learning, leading many researchers to be interested in further research (Irwanto et al., 2022). Augmented Reality keywords, critical thinking skills, and science learning provide opportunities for students to see the world around them in new ways (Santos et al., 2016); provide engaging and realistic learning experiences (Thees et al., 2020); and help students to be actively involved in authentic exploration in real life so that it is effective in improving the understanding of abstract concepts and critical thinking skills that are in accordance with the scientific process in science learning (Yoon et al., 2017; Eric Klopfer, 2019; Jdaitawi et al., 2022). Increasing research trends can broaden perception and the ability to adapt quickly to contexts, thus contributing to the creation of new media to deliver content, especially science learning to students (Hugues & Fuchs, 2011).

Augmented Reality keywords, critical thinking skills, and science learning in 2016, 2017, and 2018 were low due to low awareness of the technology and limited financial investment, which hampered the successful implementation and sustainability of digital

heritage initiatives (Yuen et al., 2011); Garzón et al., 2020; Real-world examples and empirical documentation in the field and laboratory studies on Augmented Reality are still limited (Jakobowsky et al., 2025; Ikram, 2025). Difficulties in measuring critical thinking objectively in various contexts have limited research on critical thinking skills (Wijayatunga et al., 2024). Limited teacher efficacy towards technology and educational innovation has slowed the development of 21st-century skills-based learning, one of which is critical thinking (Maria Angele Dano, 2024). The research literature on critical thinking skills has gaps in explaining the processes of reflection and metacognition (Marulis, 2025). The lack of cross-disciplinary collaboration in research design hinders a comprehensive understanding of the formation and facilitation of critical thinking (Seran et al., 2024).

Ways to increase scientific publications on Augmented Reality, critical thinking skills, and science learning include supporting research and development on key terms, improving the delivery of the use and benefits of new learning media (Garzón et al., 2020). The development of user-based Augmented Reality platforms can be achieved through multidisciplinary collaboration between engineers, psychologists, and educators (Bradwell et al., 2025). Research on feedback on the potential training benefits derived from the use of advanced technologies such as Augmented Reality in improving critical thinking skills can be conducted to increase scientific publications on key terms (Nguyen Mau Duc, Pham NGoc Son, 2025).

The keywords Augmented Reality, Critical thinking, and science learning are interrelated. Critical thinking skills serve as the core of higher-order thinking required for conceptual understanding and scientific problem-solving in science learning (Nusroh et al., 2022; Kusumaningrum & Hayat, 2025). Augmented Reality offers the unique capability of combining three-dimensional digital representations with real-world objects in real time, enabling the visualization of abstract natural processes (Mansour et al., 2025). Abstract visualizations can support evidential exploration and hypothesis testing by students, for example, in force fields, molecular structures, or system dynamics (Evagorou et al., 2015). Augmented Reality can be a pedagogical medium that facilitates critical thinking practices because it makes hidden variables observable and manipulable in the context of science learning (Alkhabra et al., 2023).

CONCLUSION

Based on a bibliometric study of scientific publications, the keywords Augmented Reality, critical thinking skills, and science learning in 2015-2025 have a pattern with an increasing trend, but the overall percentage is less than 50% so that research is still limited. The keywords Augmented Reality, critical thinking skills, and science learning are among the newest keywords as evidenced by the color overlay and are interconnected with each other. Based on the results of the study, it shows that further and in-depth research is needed so that the percentage of keywords Augmented Reality, critical thinking skills, and science learning increases. Research on other 21st-century skills needs to be conducted using Augmented Reality to determine trends and the latest keywords.

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