Mapping Global Research Trends on Citizenship in Science and the Science-Technology-Society Approach for Developing Critical Thinking Skills: A Bibliometric Analysis Using VOSviewer

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Abstract

This study aims to map research trends on citizenship in science and the science-technology-society approach in relation to the development of critical thinking skills over the past decade. The method used is bibliometric analysis with the help of VOSviewer software. Data were collected from the Scopus database using the keywords with a publication range of 2021–2025. Relevant articles were then analyzed to produce visualizations in the form of network visualization, overlay visualization, and density visualization. The analysis results show that the keyword critical thinking is the main and most dominant focus, with a close relationship to the terms *critical thinking skill*, effect, and relationship. Another prominent cluster is the integration of science, technology, and society and its connection to innovation and the environment. In addition, the keywords citizenship and education also emerged significantly, emphasizing the importance of integrating scientific citizenship in science education. The overlay visualization analysis reveals a shift in trends, with early research emphasizing critical thinking skills, while more recent publications focus on the integration of STS, citizenship, and contemporary issues such as the environment and innovation. These findings demonstrate that international literature not only positions critical thinking as a cognitive skill but also links it to social responsibility, civic literacy, and readiness to face global challenges. The implications of this research underscore the urgency of developing a learning model that integrates the citizenship in science framework with the STS approach to strengthen critical thinking skills and shape students as 21st-century scientific citizens.

1. Introduction

Science education in the 21st century focuses not only on mastering concepts but also on developing skills relevant to global challenges (Sanjiartha et al., 2024; Yunita & Mandasari, 2025). Students are expected not only to understand theory but also to be able to apply science in everyday life contexts. Therefore, science education needs to be directed towards achieving comprehensive scientific literacy. This literacy encompasses the ability to understand phenomena, use scientific knowledge in decision-making, and be critical of scientific and technological issues (Febriana et al., 2025; Purnawati & Yakin, 2025). Thus, science education plays a crucial role in developing students who are competent, adaptive, and ready to face changing times.

The concept of Citizenship in Science addresses the need for science learning oriented towards the development of scientific citizens. Citizenship in Science emphasizes the importance of students' roles as individuals who not only understand science but also have the awareness to actively participate in social life (Ekaputri et al., 2025; Ginanjar et al., 2025). Students who possess scientific citizenship are expected to be able to make responsible decisions in social, environmental, and technological contexts. This aligns with the notion that science does not stand alone but is always connected to aspects of human life. By integrating Citizenship in Science into learning, students are equipped with both intellectual abilities and moral responsibilities as citizens.

The Science Technology Society (STS) approach is one strategy that can be used to strengthen the integration of Citizenship in Science in science learning. STS focuses on the relationship between scientific knowledge, technological developments, and their implications for society (Sofiah et al., 2020; Ulfah et al., 2020). Through this approach, students are trained to view science not simply as a collection of concepts, but as a living science that interacts with social needs. STS-based learning encourages students to engage with real-world issues such as the environment, health, and energy. Thus, the STS approach is relevant for developing conceptual understanding as well as social awareness in students.

One of the key skills targeted in the integration of Citizenship in Science and STS is critical thinking. Critical thinking is necessary for students to analyze information, evaluate arguments, and make decisions based on evidence (Ariadila et al., 2023; Shanti et al., 2017). In the context of science learning, this skill encourages students to not only receive information but also assess its validity and relevance. Learning that emphasizes real-world science and technology issues can provide students with opportunities to practice critical thinking (Davidi et al., 2021; Nurhalizah et al., 2025). Therefore, critical thinking is an important bridge connecting scientific literacy, citizenship, and 21st-century skills.

However, based on a literature review, there is still limited research specifically examining the integration of Citizenship in Science with the STS approach in relation to critical thinking. Most studies tend to focus on the application of STS to improve learning outcomes or scientific literacy, without highlighting the aspects of scientific citizenship. Furthermore, studies linking these three aspects are still separate and have not been comprehensively mapped. This indicates a research gap that needs to be filled to enrich the discourse on science education. Therefore, an analysis capable of mapping emerging trends, collaborations, and key themes in research related to this topic is needed.

Based on these issues, this study uses bibliometric analysis with the help of VOSviewer software to map publications over the past ten years. This analysis is expected to provide a comprehensive overview of research developments, collaborations between authors, and emerging dominant themes. The novelty of this research lies in its attempt to integrate aspects of Citizenship in Science, STS, and critical thinking within a single publication trend analysis framework. The results are expected to serve as a foundation for further studies related to innovations in science learning. Therefore, the purpose of this study is to map research trends on Citizenship in Science and Science Technology Society (STS) in relation to the development of critical thinking skills over the past decade.

2. Research Methods

Research Design

This study uses a bibliometric approach with descriptive analysis. The primary objective of this bibliometric analysis is to map publication trends on Citizenship in Science and the Science Technology Society (STS) approach in relation to the development of critical thinking skills during the period 2021–2025 (Handaningrum & Chariri, 2025; Wardhana et al., 2023).

Data Sources

Research data was obtained from the Scopus database due to its broad and representative publication coverage in the field of science education. Article searches were conducted using the keywords: "Citizenship in Science," "Science Technology Society," and "Critical Thinking." The publication period was limited to 2021–2025 to capture the latest trends.

Research Procedure

The research procedure began with a search for articles in the Scopus database using a combination of keywords and the 2021–2025 filter. The search results were then filtered to ensure there were no duplications and that only articles relevant to the research topic were retained. After data cleaning, article metadata, including title, author, keywords, and citation count, was extracted and uploaded to VOSviewer software. This software performed a visualization analysis in the form of a keyword co-occurrence map to map research trends and relationships between concepts (Ananda et al., 2025; Soesanto & Handalani, 2023).

Data Collection Instruments and Techniques

The primary instrument in this study was VOSviewer software version 1.6.20, which was used to analyze and visualize relationships between keywords. Data was collected from the Scopus database, selected for its extensive and reputable publication coverage. The data collection process used a combination of the keywords "Citizenship in Science," "Science Technology Society," and "Critical Thinking." Search results were filtered based on publication years 2021–2025 to ensure that the articles retrieved were truly relevant to the research objectives. All obtained article metadata was then exported in RIS/CSV format, suitable for further processing using VOSviewer.

Data analysis techniques

Data analysis was conducted by interpreting the visualization results generated by VOSviewer. Keyword network maps were analyzed to identify the most frequently occurring keywords, the number of clusters formed, and the relationships between keywords in the literature. From these visualizations, dominant themes emerging over the 2021–2025 timeframe were identified. Furthermore, the analysis focused on how the emerging keyword clusters illustrate research directions in the fields of Citizenship in Science and STS and their relevance to the development of critical thinking skills.

3. Result and Discussion

The results of the bibliometric analysis using VOSviewer produced a network visualization showing the interrelationships between key keywords in publications related to Citizenship in Science, Science Technology Society (STS), and critical thinking skills. The results can be seen in the image below:

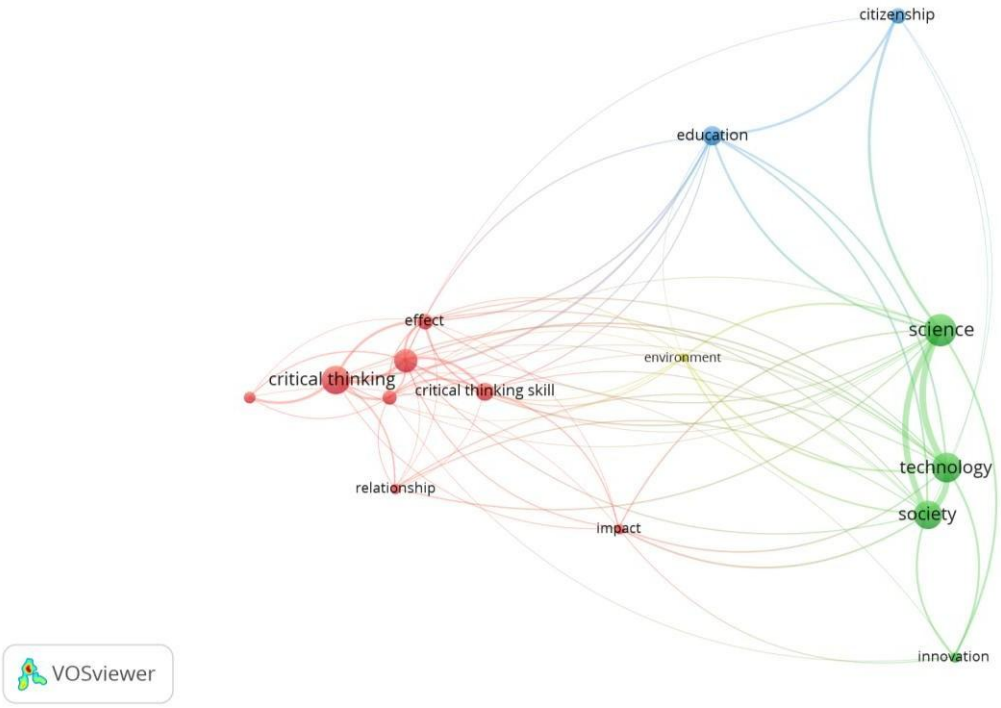

Fig 1. Network VIsualization

The network map in Figure 1 shows that the term "critical thinking" is the most dominant keyword and occupies a central position within the red cluster. This keyword is strongly connected to other terms such as critical thinking skills, effect, relationship, impact, and higher education. This indicates that the study of critical thinking is not only a primary focus but is also widely studied in the context of higher education and its impact on science learning.

Meanwhile, the green cluster displays closely interconnected keywords such as science, technology, society, and innovation. This cluster emphasizes the importance of the STS approach to science learning, which places issues of science, technology, and society as a whole to develop 21st-century skills.

The blue cluster, centered on the words "citizenship" and "education," highlights the link between science education and the formation of citizens with scientific character. This indicates that the integration of "Citizenship in Science" into the science curriculum holds a significant position in the international literature. Furthermore, a relatively smaller yellow cluster, such as "environment," indicates a research direction linking environmental issues to science education, citizenship, and the development of critical thinking.

Overall, the results of this mapping show that international literature on Citizenship in Science integrated with STS focuses largely on developing critical thinking, developing scientific citizenship, and implementing learning based on social and environmental issues. These findings reinforce the urgency of integrating STS and citizenship in science learning to prepare students to face global challenges.

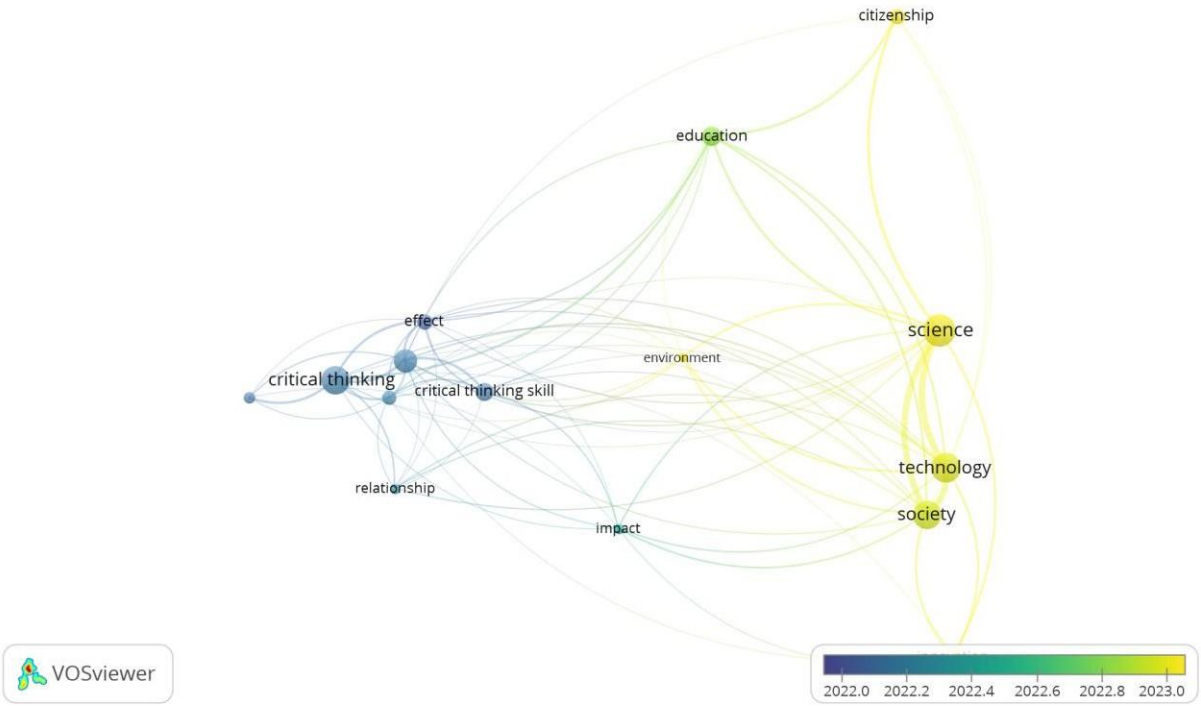

Fig 2. Overlay Visualization

In addition to keyword network mapping, an overlay visualization analysis was also conducted to determine the temporal development of research during the 2021–2025 period. Darker colors (purple–blue) indicate keywords that appeared more frequently at the beginning of the period (2021–2022), while lighter colors (green–yellow) indicate keywords that appeared more frequently in more recent years (2023–2025). Based on the overlay visualization results, it appears that the term "critical thinking" and its derivatives, such as critical thinking skills, relationships, and effects, were predominantly used at the beginning of the period (2021–2022). This indicates that research in the initial phase emphasized the exploration of critical thinking concepts in the context of science education.

Meanwhile, the terms "science," "technology," and "society" tended to be colored yellow, indicating they appeared more frequently in more recent publications (2023–2025). This finding indicates a shift in research focus toward integrating STS approaches to support scientific literacy and strengthen students' scientific citizenship character. Furthermore, keywords such as "citizenship" and "education" also appear in relatively brighter colors, indicating increased research attention to the integration of citizenship aspects into science learning in recent years.

This pattern demonstrates the evolution of research from an initial focus on critical thinking skills to a broader study of the integration of STS and citizenship in science education. This aligns with the needs of 21st-century learning development, which emphasizes not only cognitive skills but also social responsibility, innovation, and civic literacy.

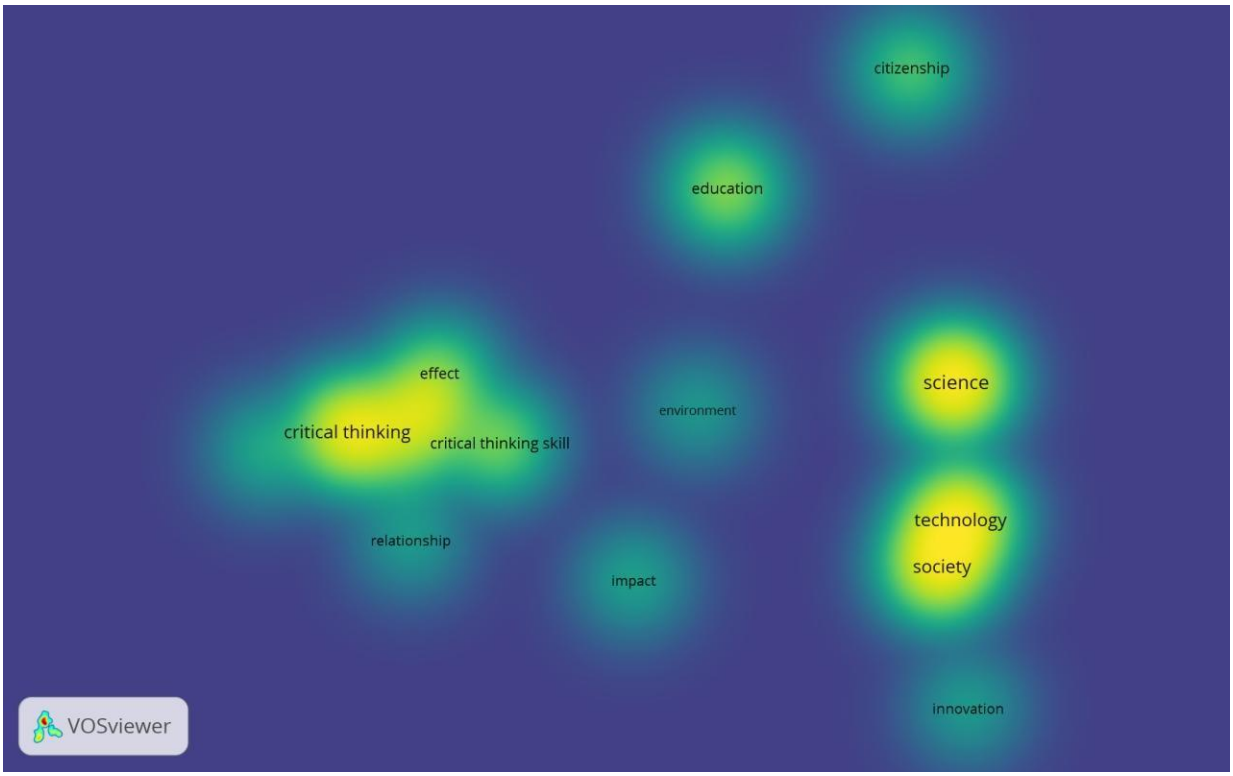

Fig 3. Density Visualization

Based on the analysis using VOSviewer, a density map visualization was obtained showing the interrelationships between research keywords. The keyword "critical thinking" appears as the center with the brightest color intensity, indicating that this topic has the highest frequency of occurrence and is a primary focus within the research network. Other keywords closely related to critical thinking include critical thinking skills, effects, and relationships.

Furthermore, other keyword groups also appear with varying degrees of density, such as education and citizenship at the top of the map, science, technology, and society on the right side of the map, and environment, impact, and innovation clustered around them. Green to yellow colors indicate moderate interconnectedness, while blue indicates lower interconnectedness. The mapping results show that critical thinking is a central topic in research, with a strong link to the development of critical thinking skills and its relationship to effects and relationships with other variables. This confirms that critical thinking remains a primary focus in education and science studies.

The proximity of the keywords "education" and "citizenship" indicates a relationship between the development of critical thinking skills and the role of education and the formation of good citizens (scientific citizenship). On the other hand, the emergence of the keywords "science," "technology," and "society" forms a distinct cluster that emphasizes the integration of science and technology, and their implications for society. The presence of the keywords "innovation" and "environment" also broadens the scope, demonstrating that research on critical thinking is not limited to the cognitive domain, but also addresses social, environmental, and innovation issues. Thus, these results underscore the importance of developing critical thinking skills as a core topic related to various aspects, from education, science, and technology to the role of society in addressing global challenges.

These bibliometric findings not only demonstrate the dominance of critical thinking topics but also demonstrate a close connection with the concept of citizenship and the STS approach. This aligns with previous research that emphasized that critical thinking skills cannot develop optimally if focused solely on the cognitive domain, but rather need to be linked to social, technological, and civic contexts.

The shift in focus from early research that emphasized the exploration of critical thinking skills to the integration of issues of science, technology, and society in the more recent period indicates that 21st-century learning is beginning to be directed toward developing scientific citizenship. This is important because students are faced with global issues such as climate change, energy crises, and the development of digital technology that require the ability to make evidence-based decisions while also having social responsibility.

Furthermore, the presence of keywords such as innovation and environment indicates that international literature reviews are beginning to emphasize the importance of linking science to sustainability issues. Therefore, the integration of citizenship in science and STS not only supports critical thinking skills but also shapes students who are capable of becoming agents of change in society.

The implications of these findings suggest that integrating citizenship in science with a science, technology, society (STS) approach has the potential to strengthen the development of students' critical thinking skills in science learning. Bibliometric results showing the close relationship between critical thinking, education, citizenship, and global issues such as the environment and innovation indicate that science learning is no longer simply oriented toward conceptual understanding but must also be directed toward developing scientific citizens capable of reflective thinking, making evidence-based decisions, and being responsible for social and environmental impacts. Therefore, further research is needed to develop learning models that integrate aspects of scientific citizenship with contemporary science and technology issues, so that students are not only cognitively skilled but also socially sensitive and prepared to face the challenges of the 21st century.

4. Conclusions

Bibliometric analysis results indicate that critical thinking is a major focus of research related to citizenship in science and the science-technology-society (STS) approach. Keyword network mapping confirms that the development of critical thinking skills is closely related to education, scientific citizenship, and the integration of science, technology, and society issues. Furthermore, recent research trends indicate a shift in focus from simply exploring critical thinking skills to integrating aspects of citizenship, innovation, and the environment into science learning. These findings emphasize the urgency of STS-based learning supported by the citizenship in science framework to shape students who are not only critical thinkers but also socially responsible and ready to face global challenges. Further research is recommended to develop learning models that explicitly integrate aspects of citizenship in science with the STS approach to strengthen students' critical thinking skills.

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