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A Bibliometric Analysis of Critical and Creative Thinking in Elementary School Mathematics Learning

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Abstract

Through a bibliometric approach, this study aims to analyze trends, main focuses, and potential future research themes related to critical and creative thinking skills in mathematics learning at the elementary school level. The data were obtained from the Scopus database covering the years 1997–2025 with the search keywords "critical thinking" OR "creative thinking" AND math* AND "elementary school", resulting in 125 documents analyzed using Biblioshiny R and VOSviewer software. The analysis results show that publications on this topic have increased significantly since 2016, with Indonesia having the highest number of publications. However, the United States and Taiwan dominate in terms of citation impact. Four main clusters were identified: innovative learning approaches (including STEM and problem-based learning), elementary education contexts, curriculum development and engineering education, and strengthening critical thinking skills through geometry and problem solving. Bibliometric visualization also shows that topics such as "creative thinking", "teaching and learning", and "educational computing" are growing and promising areas for further research. This study recommends integrating interdisciplinary and technological approaches in curriculum development and the need for increased international collaboration to strengthen research impact. These findings provide an important contribution to mapping the scientific landscape and the direction of developing mathematics learning that fosters higher-order thinking skills from an elementary school.

Keywords: critical thinking, creative thinking, mathematics learning, elementary school, bibliometric analysis, vosviewer

INTRODUCTION

Critical and creative thinking are cognitive skills that play an important role in students' learning and problem-solving abilities. Critical thinking is the ability to analyze, evaluate, interpret, and make decisions logically based on evidence and valid reasoning, enabling a person to objectively assess the truth or quality of information(Khafah et al., 2023). Meanwhile, creative thinking is the ability to generate new, diverse, and original ideas, strategies, or solutions through the development of imagination and the integration of various pieces of information(Kalın & Öztürk, 2024). In elementary school mathematics learning, these skills help students develop a deeper understanding of mathematical concepts, improve their ability to analyse problems, and encourage innovative approaches to finding solutions (Davidi et al., 2021). Developing critical thinking skills allows students to evaluate information systematically, while creative thinking skills encourage students to explore various solutions and generate alternative and original solution strategies (Cahyaningsih & Nahdi, 2021; Rezaei & shirazi, 2024). These skills are essential for success in mathematics and real-world applications outside the classroom.

The importance of integrating critical and creative thinking skills in mathematics education has been emphasised in various studies. Research shows that students with good critical thinking skills become more adept at reasoning, making connections, and applying mathematical knowledge in diverse situations (Achsin, 2016; Ulfa et al., 2019). Likewise, creative thinking in mathematics allows students to solve problems from different perspectives and generate unique solutions (Prayudho, 2024; Suardipa, 2020; Trisnani et al., 2024). However, mathematics instruction still focuses on rote learning and procedural knowledge, often neglecting opportunities to develop higher-order thinking skills (Ariyana et al., 2018). A well-structured mathematics curriculum that combines critical and creative thinking skills can improve students' cognitive development (Saraswati & Agustika, 2020). Teachers play an important role in developing these skills by implementing student-centred teaching strategies, such as inquiry-based learning, problem-solving activities, and open-ended questions (Akhyar et al., 2024). Encouraging students to provide reasons, justify answers, and explore problem-solving methods can result in more meaningful learning experiences. In addition, integrating technology and interactive learning tools can provide additional support in engaging students and encouraging critical and creative thinking skills in mathematics learning (Marpaung, 2024; Simanjuntak & Murniarti, 2024; Widodo et al., 2021).

Recent bibliometric studies on critical and creative thinking skills in mathematics education have highlighted the growing research interest in this area. Several analyses using databases such as Scopus and Google Scholar have shown an increasing number of publications on mathematical critical thinking, especially in secondary education. A study by Yanuari & Turmudi (2023) revealed that research trends primarily focus on critical thinking skills at the secondary level, with co-occurrence analysis showing limited exploration in primary education. Orhan (2023) highlighted that research on critical thinking is growing, with significant trends including higher education, 21st-century literacy skills, educational psychology, educational technology, and the influence of

student-centred learning strategies on critical thinking. Similarly, Farman et al., (2022) explored creative thinking skills in mathematics, but noted that research primarily concentrated on specific mathematical domains such as algebra and geometry, while areas such as statistics and probability were underrepresented. These bibliometric findings highlight the increasing academic focus on critical and creative thinking skills in mathematics, but also indicate gaps that require further exploration.

Although research on critical and creative thinking skills in mathematics education continues to grow, there is still a significant gap in research focusing on mathematics at the elementary school level. Most existing bibliometric analyses have concentrated on secondary education, thus lacking comprehensive insights into how these cognitive skills are developed in elementary school students. Although previous research has explored individual aspects of critical and creative thinking skills, research integrating both dimensions in elementary school mathematics is scarce. Furthermore, existing research has focused on specific mathematical topics, often neglecting broader interdisciplinary relationships and real-world applications. Therefore, more extensive research is needed to understand how these two skills develop and interact with each other at the elementary school level.

This study offers a new contribution by simultaneously analysing the evolution of critical thinking and creative thinking research at the elementary school level through a bibliometric approach. Unlike previous studies that only focused on one aspect, this study aims to examine how these two skills develop in the academic realm, the emerging main trends, and potential research opportunities for further research Additionally, this study utilizes the Scopus database and analytical tools such as VOSviewer and Biblioshiny R. This study is guided by three research questions.

1. What are the global publication trends in research on critical and creative thinking in elementary school mathematics learning?
2. What are the main research areas in studies of critical and creative thinking in elementary school mathematics learning?
3. What potential future research themes can be identified from the bibliometric mapping?

METHODS

This study uses a bibliometric analysis approach to examine data sets related to research on critical and creative thinking skills at the elementary school level. The research data were obtained from the Scopus database on March 3, 2025. Scopus was chosen because, Scopus is a multidisciplinary, curated database with structured metadata suitable for bibliometric analysis. In addition, Scopus is a reputable international journal indexer widely used by researchers and provides a variety of scientific literature (Nasrum et al., 2025).

This study carefully selects the right keywords to ensure the availability of comprehensive metadata in the research of critical and creative thinking skills at the elementary school level. The search keywords are carefully considered in this study,

which include all related keywords, namely ("critical thinking" OR "creative thinking") AND math* and "elementary school". The research process includes design, data collection, analysis, visualisation, and interpretation, as shown in Figure 1.

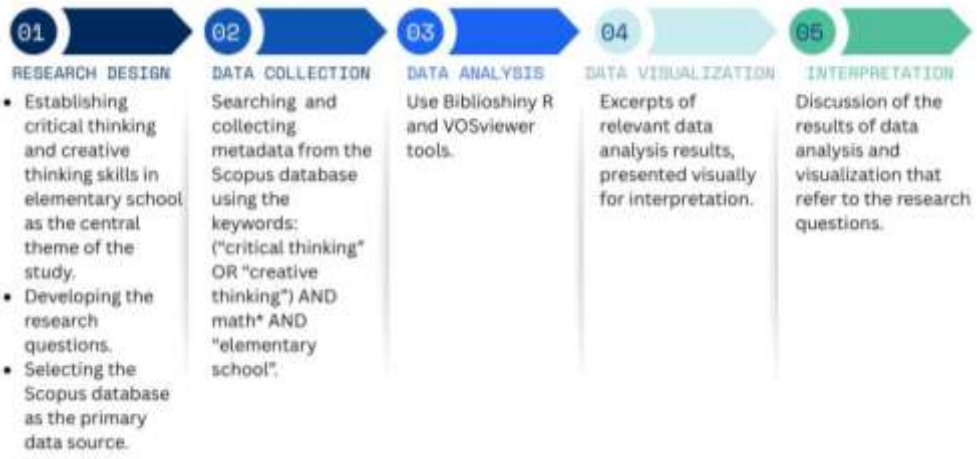

Figure 1. Steps of a study investigation (Adapted from (Zhu et al., 2023))

In the research design stage, several main steps were taken, namely determining the central theme of critical thinking and creative thinking at the elementary school level as the focus of the research, formulating research questions to direct the analysis of the research results, and selecting the Scopus database as the primary source of data collection. In the data collection process, 125 published documents containing the words ("critical thinking" OR "creative thinking") AND math** and "elementary school" were taken from Scopus without going through a filtering process. These documents were selected because they met the scope of the study, focusing on critical thinking and creative thinking in mathematics education at the elementary school level. The dataset was considered sufficient to provide a comprehensive overview of publication trends, research productivity, influential authors, collaboration networks, and emerging themes within the research field. All metadata were exported in Comma Separated Value (CSV) format for further analysis. such as authors, title, abstract, keywords, affiliations, citations, source title, and references.

The data analysis phase began after all the data had been collected. This analysis included mapping the research landscape, identifying publication trends over time, and analysing keywords to provide a visual overview of critical and creative thinking studies at the elementary school level (Donthu et al., 2021). The analysis process was carried out using Biblioshiny R and VOSviewer, which were chosen because of their ease of use and nature as open-source software (Nasrum et al., 2025; Salido et al., 2024). In the initial stage of the analysis, Biblioshiny R was used to display the research landscape and publication trends, including the number of documents and citations from all publications, publication patterns since the first year of entry into the Scopus database, influential authors, countries with the most publications, and authors with the highest citation rates. Furthermore, VOSviewer was used to visualise the relationships between keywords to identify key issues in critical and creative thinking studies at the elementary school level

and to reveal future research opportunities. In this study, the minimum occurrence threshold for keywords in VOSviewer is 3.

The data visualisation process is carried out simultaneously with data analysis, where the analysis results are displayed in the form of visual representations that support the study's main findings. These visualisations are then interpreted and discussed as part of a more in-depth analysis. Data interpretation aims to answer research questions, including identifying publication trends, key research areas, authors and countries that significantly influence the study of critical and creative thinking in elementary school, and directions for future research development.

RESULTS AND DISCUSSION

This section discusses the main findings and discussions from the data analysis. Some key insights include an overview of global research trends, key themes in critical and creative thinking studies at the primary school level, and potential future research themes.

Overviews of global trends in critical thinking and creative thinking in elementary school

Productive countries in publications

Table 1 shows the top ten countries by corresponding author affiliation with the highest number of publications from 1997 to 2025, based on the Biblioshiny analysis results..

Tabel 1. Top Ten Countries of Corresponding Authors

Country	Documents	Citations	Total Link Strength
Indonesia	61	199	6
United States	17	304	5
Taiwan	6	203	2
Malaysia	3	18	3
China	3	5	2
Germany	3	20	1
Netherlands	3	39	1
Australia	2	28	2
Denmark	2	40	1
Japan	2	19	1

Table 1 presents data on the number of documents, citations, and link strength from various countries in research on critical and creative thinking skills in elementary school mathematics learning. Indonesia is in the top position with 61 documents, obtaining 199 citations, and has a total link strength of 6, indicating an active role in this research. The United States, although only having 17 documents, recorded the highest number of citations (304), indicating that research from the country has a greater academic impact. Taiwan has many citations (203) with only six documents, indicating higher citation impact. Meanwhile, other countries such as Malaysia, China, Germany, the Netherlands, Australia, Denmark, and Japan have smaller contributions in the number of documents and citations. However, they are still involved in the research network.

Based on the most significant number of publications in research on critical and creative thinking skills in elementary school mathematics learning, the citation impact of these publications is still lower than that of those from the United States and Taiwan. This may indicate that although many studies are conducted in Indonesia, publications from other countries have higher citation impact or influence in the global academic community. Factors such as journal reputation, level of international collaboration, and relevance of research to global issues can affect the number of citations. In addition, the total link strength indicates a country's connectivity level in the research network, where Indonesia and the United States have greater involvement than other countries. Thus, to increase academic impact, researchers in Indonesia need to strengthen international collaboration, publish in highly reputable journals, and ensure their research is relevant to global challenges in elementary school mathematics learning.

Most Global Cited Documents

Most global cited documents with the highest number of publications from 1997 to 2025 are shown in Table 2.

Tabel 2. Most Global Cited Documents

Autohor	Documents	Citations
Leung, Shukkwan S	4	125
Bonotto c.	3	85
Faber, Malinda	2	65
Dewolf, Tinne	2	52
Santo, Lisa Dal	2	49
Özden, Mustafa	2	44
Lu, Shih-Yun	2	39
Leung, SK-S.	2	30
O'Connor, Erin E.	2	28
Sternberg, Robert J.	1	28

Based on the data obtained from the citation analysis, it can be seen that the authors with the highest citations are Leung Shukkwan S, with a total of 125 citations from one document. Followed by Bonotto C. with 85 citations and Faber M. and colleagues with 65 citations. All authors on this list have at least one document that has been analyzed. The total citations vary between 28 and 125, indicating a significant difference in the academic influence of each publication on subsequent research.

The high number of citations obtained by Leung (1997) indicates that their work makes a substantial contribution to the field of study, most likely due to the relevance of the topic, strong methodology, or significant findings. Differences in the number of citations between authors can be caused by various factors such as the year of publication, the journal's scope, and the topic's relevance to current research needs. This data can provide an overview of the most influential authors in a particular study topic, and can be an important reference for further research.

Publication Trends

The publication trend of studies on critical and creative thinking in elementary school from 1997 to 2025 is shown in Figure 2.

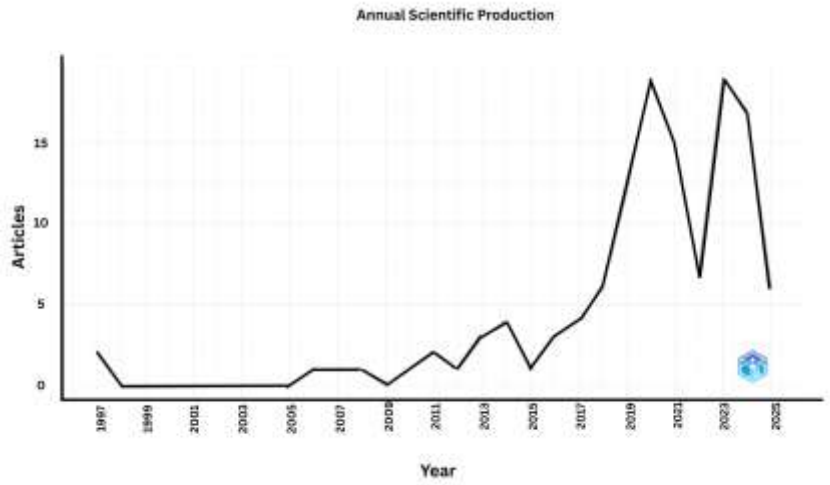

Figure 2. Publication trends

The annual scientific production graph shows a significant upward trend from year to year, especially after 2015. In the early period between 1997 and 2010, the number of articles published each year was relatively low, with most years showing only one or even zero publications. However, since 2016, the number of publications has been rising steadily, peaking in 2020 and 2023 with more than 18 articles published. This is due to the growing emphasis on 21st-century skills, STEM education, HOTS-oriented curricula, and educational technology. After 2019, there was a sharp decline in 2021, but the trend rose again in 2023 before finally decreasing again in 2024. This is because it is still in the indexing process.

Most Relevant Resource

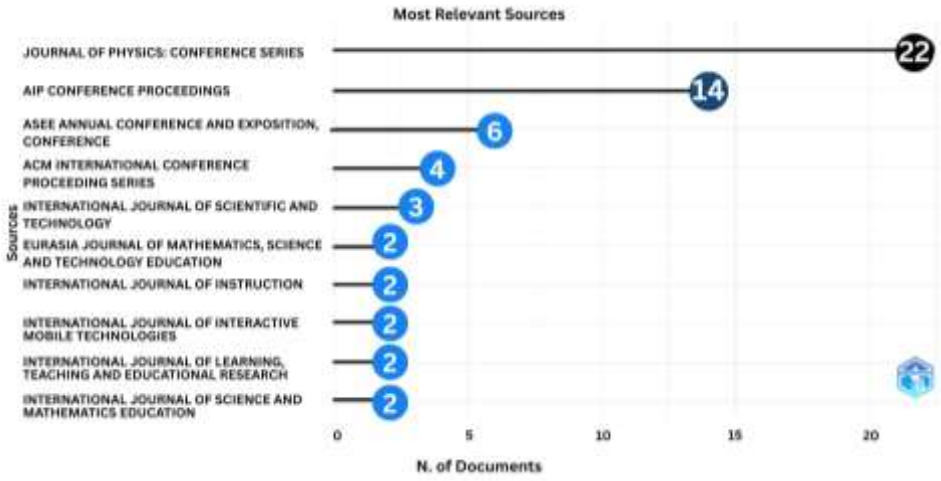

Figure 3. Most Relevant Resource

The figure shows the ten most relevant journal or proceedings sources based on the number of published documents related to critical and creative thinking in elementary school. The Journal of Physics: Conference Series is in the top position with the most significant number of documents, 22 publications. Followed by AIP Conference Proceedings with 14 documents and ASEE Annual Conference and Exposition, Conference with six documents. Other sources have smaller contributions, with the

number of documents ranging from 2 to 4, such as ACM International Conference Proceeding Series, International Journal of Scientific and Technology, and International Journal of Science and Mathematics Education.

The dominance of sources such as the Journal of Physics: Conference Series and AIP Conference Proceedings shows that the research topic studied, namely critical and creative thinking skills in mathematics learning, is widely discussed in scientific conference forums focusing on science and technology education. This indicates that the interdisciplinary approach, which combines mathematics education with technology and science, is a significant concern in the scientific community. Meanwhile, the existence of journals such as the Eurasia Journal of Mathematics, Science and Technology and the International Journal of Instruction confirms the relevance of this research in the context of formal education and teaching strategies. The variety of these sources reflects the breadth of scope and approach in studying the topic of critical and creative thinking, both in terms of theory, teaching practice, and learning support technology.

Key research areas in critical and creative thinking

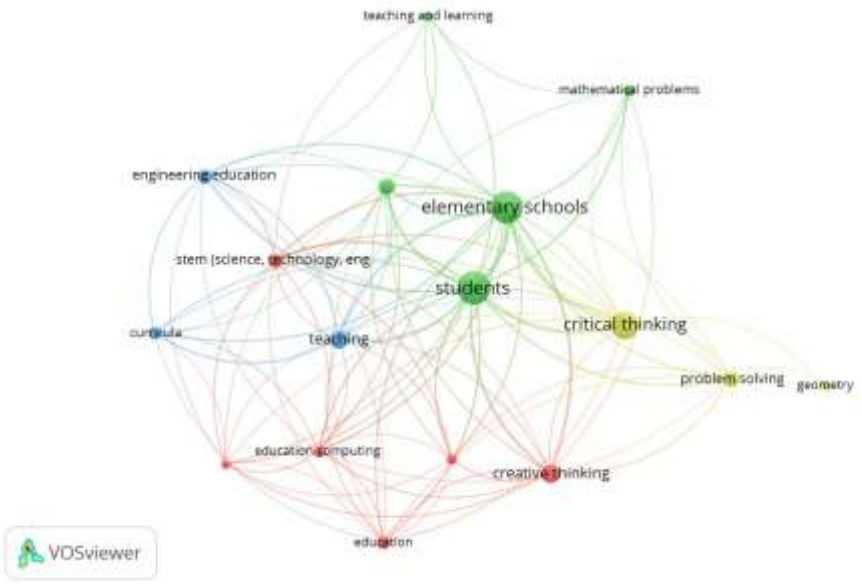

Figure 4. Key research areas in critical and creative thinking

The results of the cluster analysis produced four main groups of interrelated topics. Cluster 1 has six items highlighting innovative learning approaches such as creative thinking, problem-based learning, and STEM integration. Cluster 2 contains five items that focus on the context of elementary education, especially the process of learning mathematics in elementary schools. Cluster 3 includes three items related to curriculum development and engineering education, indicating attention to learning structure. Finally, Cluster 4 contains three items focusing on developing critical thinking through geometry and problem-solving learning. These four clusters show that the topic of critical and creative thinking skills in elementary school mathematics learning has broad and diverse dimensions, including approaches, contexts, curricula, and learning content.

The four resulting clusters reflect the diversity of focus in research related to critical and creative thinking skills in mathematics learning. Cluster 1 illustrates the shift in educational paradigms towards more innovative and integrative approaches, such as problem-based learning, technology utilisation (educational computing), and interdisciplinary approaches such as STEM. This shows that high-level thinking skills cannot be optimally developed through conventional methods, but instead need to be supported by learning strategies that can challenge students to think creatively and reflectively. On the other hand, Cluster 3 highlights the structural aspects of education, namely curriculum and engineering education. This indicates that developing a contextual curriculum responsive to the challenges of the times is crucial in forming students who are not only academically competent but also adaptive in the world of work and real life.

Meanwhile, Cluster 2 and Cluster 4 focus more on applying learning and competency development at the micro level, namely in the classroom environment and on specific content. Cluster 2 describes elementary school learning conditions, focusing on students, learning systems, and the mathematics problems faced. Research in this cluster highlights teaching practices and learning interactions that directly affect students' cognitive development. Meanwhile, Cluster 4 identifies critical thinking, geometry, and problem solving, which shows a tendency for geometry to be an effective medium in training logic, analysis, and problem-solving skills. This shows that critical thinking skills can be contextually developed through mathematics learning, emphasising concept exploration and reasoning. Thus, the overall findings from these four clusters provide an overview that the development of critical and creative thinking in mathematics learning is theoretical, applicable, and contextual, involving various aspects ranging from learning approaches, curriculum, to the content of teaching materials. This integrative approach is important so students can link mathematical concepts to real-world situations and sustainably develop high-level thinking skills (Sitorus & Masrayati, 2016).

Potential Future Research Themes in Critical and Creative Thinking in Elementary School

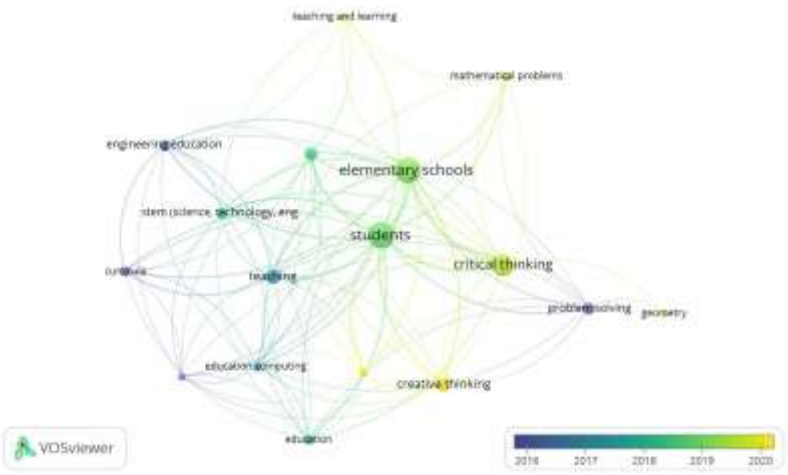

Figure 5. Potential Future Research Themes

Although the dataset covers publications through 2025, the overlay visualization displays average publication years primarily between 2016 and 2020 because VOSviewer calculates the mean publication year of each keyword based on its occurrences across all documents. As a result, keywords that have been consistently studied over a longer period tend to exhibit earlier average years. Recent publications from 2021–2025 are included in the dataset, but their influence on the average publication year remains limited due to their lower frequency and shorter citation and publication history.

This visualisation from VOSviewer shows the relationship between research topics related to critical thinking and creative thinking in elementary schools. Larger nodes such as "students", "elementary schools", and "critical thinking" indicate that these topics appear frequently and are the focus of research. The colors indicate the time progression from 2016 (dark blue) to 2020 (yellow), with some topics such as "creative thinking", "teaching and learning", and "mathematical problems" tending to be newer (yellow), indicating that these topics have become areas of increasing research in recent years.

Based on the bibliometric visualisation, it can be seen that critical thinking and creative thinking are the two main focuses in elementary school education research. The strong relationship between the terms "students", "elementary schools", and "critical thinking" shows that many studies place elementary school students as the main subjects in developing high-level thinking skills. In addition, the emergence of terms such as "problem solving" and "mathematical problems" shows that a problem-solving-based approach, especially in the context of mathematics lessons, is an effective path in developing critical thinking. This relationship also reflects the importance of teachers and learning strategies in creating a learning environment that systematically and reflectively stimulates students' thinking skills. Teachers are not only transmitters of material but also facilitators who encourage active involvement and deep thinking through appropriate learning approaches (Harahap et al., 2024; Kusuma et al., 2023).

On the other hand, the “creative thinking” theme, marked in yellow, indicates that this is a research area that has been relatively popular among researchers every year and is a field that continues to evolve. Related terms such as “educational computing”, “STEM (science, technology, engineering, and mathematics)”, and “teaching and learning” open up great opportunities for technology integration in creative learning. This shows potential directions for future research, especially in designing project-based, exploratory, and interdisciplinary learning methods that encourage students to innovate. With the development of technology and the needs of the 21st century, future research can focus more on developing curriculum and pedagogical models that can develop both types of thinking skills in a balanced manner since elementary school. 21st-century education requires students not only to master content but also to have critical and creative thinking skills to adapt to the complexities of the modern world (Arifin & Mu’id, 2024; Wijaya et al., 2016).

The bibliometric visualization highlights well-established themes such as “critical thinking,” “students,” and “elementary schools,” while also revealing emerging and relatively underexplored research areas. Keywords such as “creative thinking,” “educational computing,” “STEM (science, technology, engineering, and mathematics),”

and "teaching and learning" have more recent average publication years (yellow nodes), indicating growing scholarly interest but less dense connections than the dominant themes. This suggests opportunities for future research on how technology-enhanced learning environments, digital tools, and STEM-based instructional approaches can foster both critical and creative thinking skills among elementary school students. The limited connections among these newer keywords also imply that the integration of educational computing, interdisciplinary STEM learning, and higher-order thinking development has not yet been extensively explored. Future studies could therefore design and evaluate innovative pedagogical models, such as project-based learning, inquiry-based learning, and computational thinking activities, that integrate digital technologies while promoting both critical and creative thinking. Such investigations would help address current gaps in the literature and support educational practices aligned with 21st-century learning demands.

CONCLUSION

The data shows that Indonesia has the highest number of publications on critical and creative thinking skills in elementary school mathematics learning. However, its academic impact is still lower than that of the United States and Taiwan, which have higher citations. This reflects the importance of journal quality, international collaboration, and topic relevance to increase global influence. Leung S.S. emerged as the most influential author with the most citations, indicating that the quality and scope of research greatly determine its academic significance. The publication trend from 1989 to 2025 shows a significant increase, especially after 2015, with peaks in 2019 and 2023, in line with the increasing attention to developing higher-order thinking skills in elementary education. The publication sources are dominated by science and technology-oriented scientific journals and proceedings such as the Journal of Physics: Conference Series, indicating the importance of an interdisciplinary approach.

Cluster analysis revealed that research on critical and creative thinking in elementary school mathematics falls into four primary focuses: innovative approaches such as STEM and problem-based learning, elementary school learning contexts, curriculum development and engineering education, and a focus on geometry and problem-solving. These findings suggest that higher-order thinking skills are studied from various angles, both in terms of teaching strategies, curriculum structures, and content of teaching materials, with an approach that emphasises the connection between theory and practice and contextual needs in the real world.

Bibliometric visualisation shows that topics such as critical thinking, elementary schools, and students are the primary focus of research, with problem-solving approaches in mathematics lessons being a practical pathway to developing higher-order thinking skills. Meanwhile, creative thinking has emerged as a growing research theme, especially in technology integration, such as educational computing and STEM approaches. This trend opens up great opportunities for future research, emphasising project-based and integrative learning to equip students with the critical and creative thinking skills needed to face the challenges of the 21st century.

These findings provide important practical implications for various stakeholders. For mathematics education researchers, the identified trends, influential themes, and emerging topics offer guidance for future investigations and encourage greater international collaboration to enhance research visibility and impact. For teachers, the results emphasize the importance of designing learning experiences that actively engage students in reasoning, creativity, exploration, and problem-solving through innovative instructional approaches. For curriculum developers, the findings underline the need to systematically integrate critical and creative thinking skills into curriculum objectives, learning activities, and assessment practices. Strengthening the connection between mathematics learning, technology, and real-world applications can help ensure that elementary school students are better prepared to meet future educational, social, and professional challenges.

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