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Critical Thinking in Mathematics Education: A Systematic Literature Review and Bibliometric Analysis

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Abstrak

Minat akademis terhadap berpikir kritis dalam pendidikan matematika terus meningkat, tetapi pemetaan kontribusi ilmiah yang menyeluruh masih terbatas. Studi ini memadukan tinjauan pustaka sistematis dan analisis bibliometrik untuk memetakan tren publikasi, fokus tema, dan jejaring kolaborasi riset. Menggunakan protokol PRISMA, artikel dihimpun dari Scopus dengan kata kunci "critical thinking" dan "mathematics education" hingga 3 Juli 2025. Dari 2.088 catatan awal, 142 artikel memenuhi kriteria. Analisis VOSviewer menunjukkan pertumbuhan publikasi yang stabil dalam lima tahun terakhir, dengan dominasi studi kualitatif. Tema-tema utama meliputi integrasi berpikir kritis dalam kurikulum matematika, penerapan model pembelajaran inovatif seperti Problem-Based Learning dan kelas terbalik, serta pengembangan instrumen asesmen untuk keterampilan berpikir tingkat tinggi. Tinjauan ini merangkum lima komponen inti berpikir kritis matematis: pemecahan masalah autentik, pertanyaan reflektif, penalaran, evaluasi, dan strategi metakognitif, yang mendukung pemahaman konseptual dan fleksibilitas kognitif. Implikasinya, pendidik dan peneliti perlu mengintegrasikan komponen tersebut dalam desain pembelajaran dan asesmen, serta menguji efektivitasnya melalui studi empiris pada berbagai konteks dan jenjang pendidikan.

***Kata Kunci**: Analisis Bibliometrik; Berpikir Kritis; Pendidikan Matematika; Tinjauan Literatur Sistematis.*

Abstract

Academic interest in critical thinking in mathematics education has increased, yet comprehensive mapping of scholarly contributions remains limited. This study combines a systematic literature review and bibliometric analysis to identify publication trends, key themes, and research collaboration networks. Using the PRISMA protocol, articles were retrieved from Scopus with the keywords "critical thinking" and "mathematics education," covering publications up to July 3, 2025. Of 2,088 initial records, 142 articles met the eligibility criteria. VOSviewer mapping shows steady publication growth over the past five years, with qualitative studies as the dominant approach. Major themes include integrating critical thinking into the mathematics curriculum, applying innovative instructional models such as Problem-Based Learning and flipped classrooms, and developing assessment instruments for higher-order thinking skills. This review summarizes five core components of mathematical critical thinking authentic problem solving, reflective questioning, reasoning, evaluation, and metacognitive strategies which support conceptual understanding and cognitive flexibility. These findings imply that educators and researchers should embed these components into teaching and assessment designs and examine their effectiveness through empirical studies across diverse contexts and educational levels.

Keywords: Bibliometric Analysis; Critical Thinking; Mathematics Education; Systematic Literature Review.

I. INTRODUCTION

Critical thinking is widely recognized as an essential skill in mathematics education, enabling students to confront complex problems, evaluate multiple solutions, and make informed decisions (Cahya & Juandi, 2021; Maharani et al., 2019; Susyla & Syofiana, 2019; Arofah, Ardiansyah, & Suryanti, 2025). Critical thinking not only contributes to academic achievement, but also develops competencies such as logical reasoning, problem solving, and decision making that are useful in everyday life (Alifia & Saputro, 2019; Schott, 2016; Syafril et al., 2020; Tajuddin et al., 2023).

Mathematics education aims to cultivate these skills through a variety of learning strategies and curriculum design. Research shows that higher mathematics ability is correlated with more diverse and effective critical thinking patterns (Cahya & Juandi, 2021; Afriansyah et al., 2021; Rahmasari et al., 2025). In addition, a targeted pedagogical approach, such as Realistic Mathematics Education, has been shown to significantly improve students' critical thinking skills compared to conventional learning (Cahya & Juandi, 2021; Afriansyah & Turmudi, 2022; Noverli, Nery, & Hadi, 2025).

To systematically examine the scholarly discourse on critical thinking in mathematics education, a systematic literature review (SLR) and bibliometric analysis offer complementary methodological advantages. SLR provides a structured, transparent, and replicable approach to synthesizing existing research, ensuring reliability while identifying research gaps, trends, and opportunities (Fundoni et al., 2023; García-García et al., 2017; Turk, 2021). Bibliometric analysis uses quantitative techniques to map the thematic evolution of research, measure the influence of important publications, and identify collaborative networks between authors and institutions (Gómez et al., 2025; Lim & Ghazali, 2017; Marvi & Foroudi, 2023).

In the context of mathematics education, the combination of these two methodologies offers a comprehensive view of how critical thinking has been conceptualized, researched, and applied in educational practice. This dual approach allows researchers to not only synthesize existing knowledge but also visualize the development of the field over time, identifying influential works, research focuses, and emerging new directions (Gómez et al., 2025; Sharma & Garg, 2024).

Nevertheless, prior systematic literature reviews in this area have mostly concentrated on specific purposes, such as identifying instructional approaches to improve students' critical thinking in mathematics education (Sari & Juandi, 2023; Nafiah et al., 2024) or reviewing how critical thinking is assessed within mathematics education (Azmi et al., 2025). While valuable, these reviews generally do not provide an integrated field-level map that simultaneously synthesizes evidence and visualizes publication growth, thematic clusters, and collaboration networks.

Similarly, existing bibliometric studies on critical thinking in mathematics education often use a limited time window or a narrower scope, which may not fully capture the broader evolution of the field. Therefore, this study advances the literature by integrating a PRISMA guided

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SLR with bibliometric mapping to offer a more comprehensive and up to date overview of trends, themes, and research networks in critical thinking in mathematics education.

A Systematic Literature Review (SLR) and bibliometric analysis on the topic of critical thinking in mathematics education revealed a rapidly evolving research landscape in the last decade. Quantitatively, the number of publications related to critical thinking in mathematics has increased significantly (Khusna et al., 2024). The literature review shows that the dominant focus of research is examining the relationship between critical thinking and specific teaching strategies, while studies specifically examining this topic in the context of science education at the national level are still limited (Reis Costa et al., 2021).

A Systematic Literature Review (SLR) and bibliometric analysis on the topic of critical thinking in mathematics education reveal a rapidly evolving research landscape over the past decade. Quantitatively, the number of publications related to critical thinking in mathematics has increased significantly. The literature review indicates that the dominant focus of research is examining the relationship between critical thinking and specific teaching strategies, while studies specifically examining this topic within the context of science education at the national level are still limited.

Other findings indicate that the critical thinking dispositions of first-year students in mathematics education programs are relatively low, particularly in the systematic analysis and solution of non-routine problems (Maharani et al., 2019). The bibliometric analysis makes an important contribution by mapping the most cited publication sources, countries with the highest publication performance, and the concepts most frequently discussed in research documents (Aktoprak & Hursen, 2022). This approach helps identify research gaps, motivates other researchers to fill them, and provides guidance for future research directions (Khusna et al., 2024). Among the identified gaps are the need to use a combination of qualitative and quantitative measurement instruments, studies across various curriculum contexts, and studies that reveal the perceptions of student teachers and existing teachers (Reis Costa et al., 2021).

The implementation of a SLR on this topic faces several challenges, including limited research in a national context, a lack of longitudinal studies on the long-term effects of learning models aimed at developing critical thinking skills (Fitriadi et al., 2025), and time constraints in integrating critical thinking learning into the curriculum (Asadi et al., 2025).

Future research directions include comparing the effectiveness of learning models in rural and urban elementary schools (Fitriadi et al., 2025), exploring longitudinal impacts and cross-cultural comparisons (Rothinam et al., 2025), and in-depth studies of critical thinking processes and attitudes among education students, teachers, and researchers (Aizikovitsh-Udi, 2011).

This SLR and bibliometric analysis provide a comprehensive overview of the research status, challenges, and future directions for integrating critical thinking into mathematics education. The results highlight the need for further research to close existing gaps, explore long-term implications, and broaden understanding of the cross-cultural impact of critical thinking-based mathematics learning.

This study focuses on exploring the current landscape of Critical Thinking in Mathematics Education and evaluating the ongoing relevance of this topic as a focus for future research. This study also reviews the evolution of the academic discourse on Critical Thinking in Mathematics Education. It aims to identify how this work can contribute to mathematics education practices and future research agendas. The research questions posed are:

RQ1: Is the exploration of Critical Thinking in Mathematics Education a subject that continues to hold significance for future scholarly inquiry?

RQ2: What is the allocation of research investigations related to Critical Thinking in Mathematics Education?

RQ3: What are the theoretical and practical implications from the perspective of future research?

This study uses Systematic Literature Review (SLR) and Bibliometric Analysis to address the three research questions. The systematic literature review method is appropriate for synthesizing existing research and identifying gaps, trends, and future research directions. It offers evidence-based insights that can inform educational theory, instructional design, and future inquiry. This ensures that conclusions are drawn from a broad and representative body of literature and highlight areas for further investigation. (Andreucci-Annunziata et al., 2023; Fitriadi et al., 2025; Khusna et al., 2024; Q. Wang & Abdullah, 2024). The bibliometric analysis complements the review by quantifying the distribution, influence, and thematic evolution of publications related to Critical Thinking in Mathematics Education. Using VOSviewer and the Scopus database, this study analyzes articles from various peer-reviewed journals, focusing on publications up to July 3, 2025. This methodology provides a comprehensive mapping of the development of this research area and offers a deeper understanding of its growth, key contributors, and directions for future academic exploration.

II. METHOD

This study used a systematic literature review combined with bibliometric analysis to identify research trends, patterns, and key contributors in mathematics education, with a focus on critical thinking. The review followed the PRISMA framework to ensure a transparent and replicable process (Abayeva et al., 2024; Hadi & Faradillah, 2020).

The inclusion criteria were: (1) articles published up to January 31, 2025, (2) written in English, and (3) focused on critical thinking in mathematics education. Bibliometric mapping was conducted with VOSviewer to visualize citation links, author collaboration, and keyword co-occurrence, which helps describe the structure and development of the field.

Combining SLR and bibliometrics strengthens the synthesis of evidence and

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provides a clearer map of the research landscape, including influential works and emerging themes (Donthu et al., 2021; Sillet, 2013; Supian & Ismail, 2022; Wulansari et al., 2020). It also helps explain how the field has evolved and where future research can be directed, including cross-disciplinary perspectives (Marzi et al., 2025; J. Wang et al., 2015).

Keywords were selected using a top-down process. Due to limited prior studies directly addressing this topic, the keywords “critical thinking” and “mathematics education” were applied to the title, abstract, and keywords. Scopus was used as the main database because it offers broad and reliable coverage for reviews, expert identification, and trend monitoring.

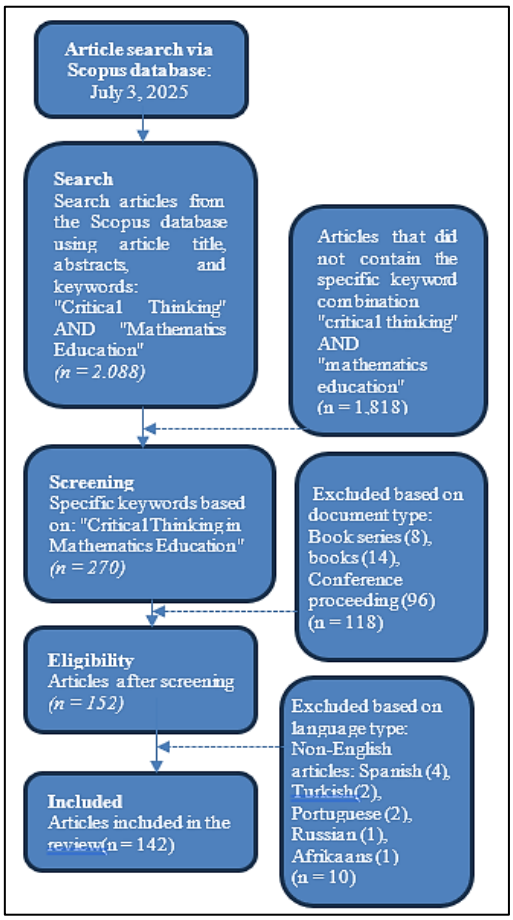


Figure 1. Systematic Literature Review Information Flow Using PRISMA.

Based on the article search conducted on July 3, 2025, through the Scopus database, using the keywords in the article title, abstract, and keyword section: "Critical Thinking" AND "Mathematics Education", a total of 2,088 documents were initially identified across various academic disciplines.

An initial screening was carried out by focusing specifically on articles that contained the exact keyword combination "Critical Thinking in Mathematics Education", narrowing the results down to 270 articles. These articles were then further screened based on document type, excluding book series (8), books (14), and conference proceedings (96). As a result, 152 articles remained eligible.

A subsequent eligibility assessment was conducted, excluding articles based on language, specifically non-English articles (Spanish (4), Turkish (2), Portuguese (2), Russian (1), Afrikaans (1)), resulting in the exclusion of 10 articles. This left a total of 142 articles that were included in the final review.

These articles were further analyzed to address the following research questions:

RQ1: Is the exploration of critical thinking in mathematics education still relevant and significant for future scholarly inquiry?

RQ2: What is the current distribution and direction of research related to critical thinking in mathematics education?

RQ3: What are the theoretical and practical implications of these findings for future research development?

III. RESULT AND DISCUSSION

The results of this study focus on findings from 142 articles in the Scopus database related to Critical Thinking in Mathematics Education. This data was retrieved by identifying the number of articles published, filtering based on relevance, document type, and language. The study also aims to highlight the most significant patterns and trends in the field, including publication volume, document types, and languages used.

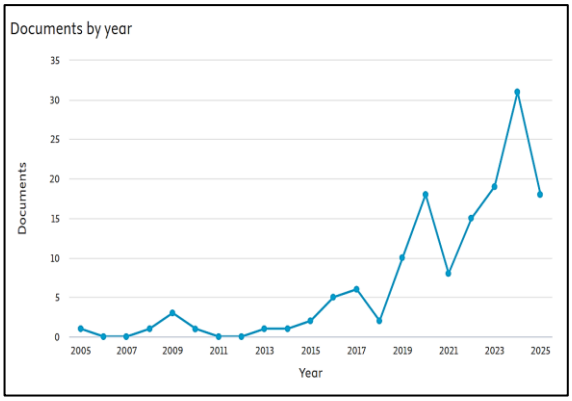
RQ1: Is the exploration of Critical Thinking in Mathematics Education a subject that continues to hold significance for future scholarly inquiry?

According to the data retrieved from the Scopus database, scholarly work related to Critical Thinking in Mathematics Education comprises 142 articles published between 2005 and 2025, spanning two decades. This indicates that the topic has gained increasing attention in the academic community over time.

As illustrated in Figure 1, the number of publications remained relatively low and fluctuated during the early years, with fewer than 5 documents per year from 2005 to 2016. A noticeable growth began in 2017, and a sharp increase occurred in 2019, followed by a peak in 2024, with a total of 31 documents published in that year alone the highest annual output within the study period. This trend highlights a growing research interest and indicates that Critical Thinking in Mathematics Education has become a prominent theme, particularly in recent years.

The consistent increase in publications, especially in the last five years, reflects the scholarly community's growing concern about the need to integrate critical thinking skills into mathematics education. This includes exploring strategies for developing students' higher-order thinking skills, redesigning curricula, and assessing the effectiveness of various pedagogical approaches.

Overall, the data suggests that Critical Thinking in Mathematics Education continues to be a significant and evolving area of research, with substantial potential for future academic exploration and practical application in educational contexts.



Source: Scopus database

Figure 2. Documents by Year.

RQ2: What is the allocation of research investigations related to Critical Thinking in Mathematics Education?

The analysis of the distribution of research on Critical Thinking in Mathematics Education across 142 articles was conducted by categorizing the documents according to classifications such as country, institutional affiliation, source, and author, with a focus on the top 10 contributors in each category. Understanding how scholarly efforts are geographically and institutionally allocated is crucial for recognizing global research

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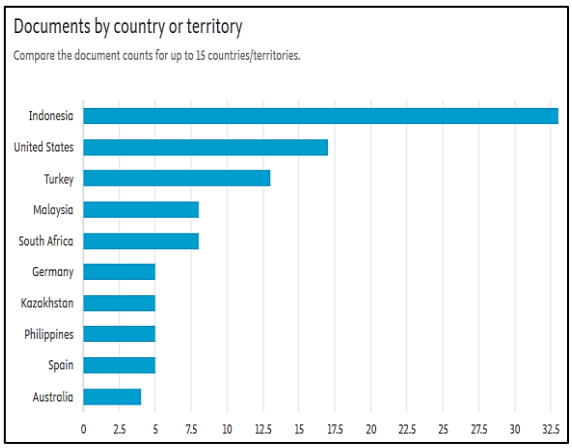
patterns, addressing disparities, and shaping a more inclusive research agenda for the integration of critical thinking into mathematics education.



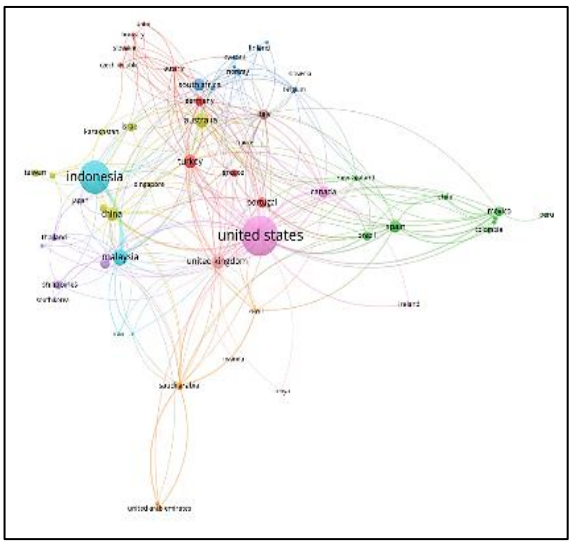
Source: Scopus database

Figure 3. Count of publications by Country or territory.

In terms of geographical distribution, the majority of scholarly contributions came from Indonesia with a total of 33 articles, indicating a strong academic focus on this topic within the region. This was followed by the United States (17 articles), Turkey (13 articles), Malaysia and South Africa (8 articles each), Germany, Kazakhstan, Philippines, and Spain (5 articles each), and Australia (4 articles), as illustrated in Figure 3.

This distribution indicates a growing recognition of the importance of developing critical thinking skills in mathematics education across various educational systems. These findings suggest that the issue of critical thinking in mathematics education is not only a concern for countries with large populations or well-established educational traditions, but also attracts global attention from different parts of the world, including developing countries.

This phenomenon reflects the global relevance of the topic of critical thinking development within the context of mathematics learning. Researchers will also examine the relationships and collaborations between countries involved in research related to this topic using VOSviewer software. This step is essential for formulating a systematic and prospective research agenda. The VOSviewer visualization results demonstrate the interconnections among nations in investigating the topic of critical thinking in mathematics education (see Figure 4).



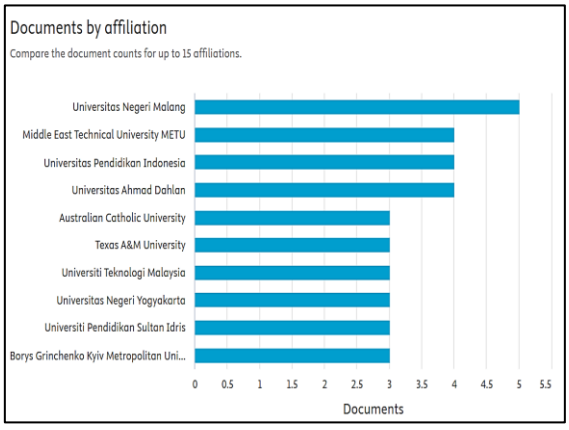
Source: Output VOS Viewer software

Figure 4. Network country visualization.

This visualization of collaborative networks shows that the United States is a major center of critical thinking research in mathematics education, with extensive connections to countries in Europe, Asia, and Latin America. Indonesia and Malaysia stand out as important centers of collaboration in Southeast Asia, closely connected to China, Taiwan, and Japan. This pattern confirms that developing

critical thinking skills in mathematics education is a global issue that receives widespread attention across regions and educational systems, with interconnected research networks across the globe.

Second, the allocation of research on critical thinking in mathematics education based on institutional affiliations is predominantly represented by Universitas Negeri Malang (Indonesia) with 5 articles. This is followed by Middle East Technical University (METU) (Turkey), Universitas Pendidikan Indonesia (Indonesia), and Universitas Ahmad Dahlan (Indonesia), each with 4 articles. Several other institutions each contributed 3 articles, including Australian Catholic University (Australia), Texas A&M University (United States), Universiti Teknologi Malaysia (Malaysia), Universitas Negeri Yogyakarta (Indonesia), Universiti Pendidikan Sultan Idris (Malaysia), and Borys Grinchenko Kyiv Metropolitan University (Ukraine) (see Figure 5).

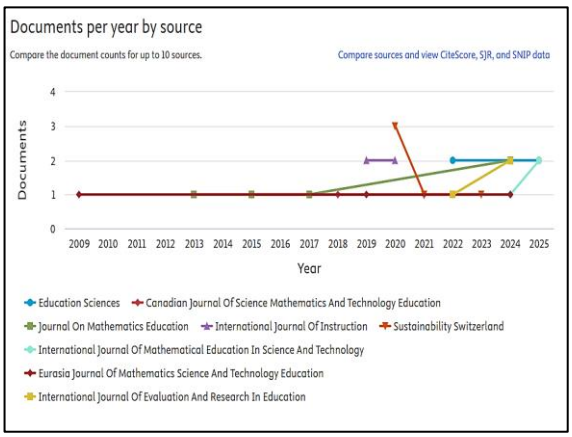


Source: Scopus database

Figure 5. Count of publications by affiliation.

The dissemination of research on critical thinking in mathematics education, based on the top 10 most productive affiliations, shows that academic interest in this topic extends beyond institutions in countries with strong educational traditions such as Indonesia and Malaysia. It also garners attention from institutions in countries that are not typically associated with a focus on mathematics education, such as Turkey, Australia, Ukraine, and the United States.

Third, publications discussing critical thinking in mathematics education are dominated by Sustainability Switzerland with 6 articles, followed by Journal On Mathematics Education with 5 articles. Other journals contributing 4 articles each include Canadian Journal of Science Mathematics and Technology Education, Education Sciences, International Journal of Instruction, and International Journal of Mathematical Education in Science and Technology. Eurasia Journal of Mathematics Science and Technology Education contributes 3 articles. Despite this, several other journals also contribute with fewer articles, reflecting the diversity of sources that play a role in disseminating research on critical thinking in mathematics education (see Figure 6).



Source: Scopus database

Figure 6. Number of articles by sources (top 10 sources).

RQ3: What are the theoretical and practical implications of these findings for future research development?

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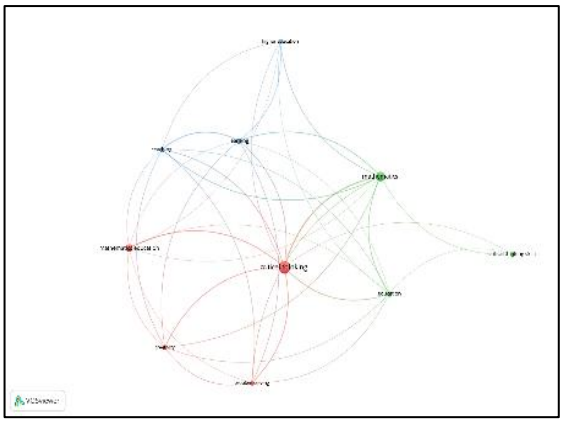
The examination was conducted on 142 manuscripts related to critical thinking in mathematics education, gathered from reputable academic sources. VOSviewer was utilized to illustrate that the results may have theoretical and practical implications for future research in this field. The metadata analysis results using VOSviewer will help researchers and educators gain a better understanding of the underlying assumptions and findings related to critical thinking in mathematics education. The bibliometric analysis results using VOSviewer can highlight which aspects of critical thinking have been extensively explored in previous studies, and which aspects still need further investigation, serving as a foundation for future inquiries. From a practical perspective, the findings will assist educators and practitioners in implementing effective strategies for enhancing critical thinking in mathematics education, contributing to its sustainable development in educational settings worldwide.

From Figure 7, the occurrences of critical thinking (52), mathematics education (49), mathematics (29), education (27), problem solving (18), teaching (15), learning (14), higher education (11), creativity (10) and, critical thinking skills (3) are highlighted, reflecting the prominence of these terms in the literature. Other keywords related to educational settings, such as student learning, cognitive skills, and curriculum development, also emerged as significant factors in promoting critical thinking in mathematics education.



Source: Output VOS Viewer software

Figure 7. Network country visualization.

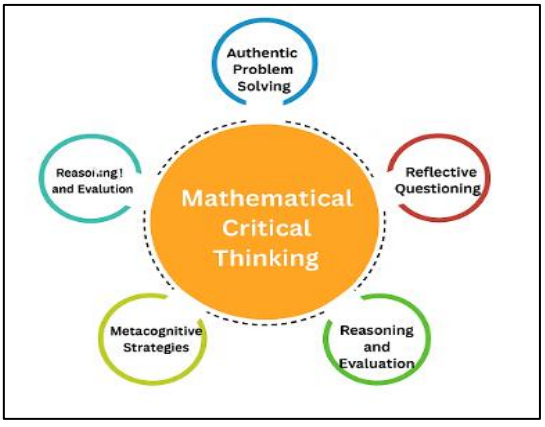
Table 1.
Total Link Strength

Rank	Keyword	Total Link Strength
1	Critical thinking	52
2	Mathematics education	49
3	Mathematics	29
4	Education	27
5	Problem solving	18
6	Teaching	15
7	Learning	14
8	Higher education	11
9	Creativity	10
10	Critical thinking skills	3

Although Figure 7 and Table 1 highlight the most frequent and strongly connected keywords, the network can be interpreted into broader thematic orientations. First, the “critical thinking problem solving reasoning” orientation indicates that many studies treat critical thinking as a capability expressed through solving non routine or authentic mathematical tasks, where students are expected to justify solutions and evaluate alternative strategies. Second, the “teaching learning mathematics education” orientation reflects research positioning critical thinking as a pedagogical process, emphasizing classroom discourse, instructional design,

and curriculum integration. Third, the "higher education creativity" orientation suggests emerging attention to critical thinking in advanced learning contexts and its linkage with creativity and higher-order competencies.

Based on the mapping results and an analysis of previous research, there is a gap in the existing literature, where the majority of studies focus on topics such as mathematics education and critical thinking. The connections between critical thinking, mathematics education, problem solving, teaching, learning, and higher education are clearly evident, indicating that these topics are interconnected. Therefore, future research should be conducted in regions with different educational contexts and diverse student populations, particularly those focusing on interdisciplinary learning and innovative educational practices. This study aims to fill the existing gaps and provide a more comprehensive understanding of critical thinking in mathematics education, especially in relation to mathematical thinking and STEM education. This understanding can help integrate critical thinking into mathematics education to improve student learning outcomes and problem-solving skills.



Source: Adapted from findings and syntheses of the latest literature (Belecina & Ocampo, 2018; Cahya & Juandi, 2021; Fitriadi et al., 2025; Khusna et al., 2024; Reis Costa et al., 2021; Schott, 2016; Szabo et al., 2020; Q. Wang & Abdullah, 2024)

Figure 8. Indicator Mathematical Crutical Thinking.

Critical thinking is an essential competency in mathematics education for meeting 21st-century challenges. It helps students analyze information logically, evaluate arguments, and solve complex problems reflectively. In mathematics learning, critical thinking appears through core components such as authentic problem solving, reflective questioning, reasoning and evaluation, and metacognitive strategies (Reis Costa et al., 2021; Q. Wang & Abdullah, 2024; Suprihatiningsih et al., 2025).

Evidence from a Systematic Literature Review (SLR) and bibliometric analysis shows that publications on critical thinking in mathematics education have grown markedly in the last five years, with research becoming more global and interdisciplinary (Nurapriani, Lestari, & Sasmi, 2025; Fitriadi et al., 2025; Khusna et al., 2024). Across studies, a consistent message is the need to integrate critical thinking into classroom practice, especially through problem-based learning, inquiry activities, and metacognitive support (Talia, 2024; Sunaryo, Solihah, & Yulisma, 2024; Cahya & Juandi, 2021; Szabo et al., 2020).

Figure 8 presents the key components of mathematical critical thinking most often discussed in the literature: (1) Authentic Problem Solving, (2) Reflective Questioning, (3) Reasoning and Evaluation, and (4) Metacognitive Strategies (Cahya & Juandi, 2021; Fitriadi et al., 2025; Khusna et

al., 2024; Reis Costa et al., 2021; Schott, 2016; Szabo et al., 2020; Luritawaty, Herman, & Prabawanto, 2022; Wang & Abdullah, 2024). These components support conceptual understanding and flexibility in solving mathematical problems.

By applying these components, mathematics instruction can focus not only on final answers but also on the process of critical, reflective, and systematic thinking. Therefore, critical thinking should be treated not only as a learning outcome but also as a key pedagogical approach in modern mathematics curricula (Andreucci-Annunziata et al., 2023).

IV. CONCLUSION

This study maps research on critical thinking in mathematics education by combining a PRISMA-guided review with bibliometric analysis of 142 Scopus-indexed articles retrieved up to July 3, 2025. The field clusters around (1) critical thinking enacted through problem solving and reasoning, (2) instructional and curricular designs that embed reflective questioning and metacognitive routines, and (3) assessment studies that operationalize critical thinking through instruments and rubrics. The findings imply that mathematics instruction should foreground justification, strategy comparison, and discussion supported by formative assessment. Key limitations include reliance on Scopus only (excluding WoS/ERIC) and a narrow keyword query that may miss related terms (e.g., higher-order thinking, reasoning). Future research should (a) expand quantitative and mixed-method designs to test causal effects, (b) conduct longitudinal and cross-cultural studies to identify contextual moderators (time, teacher readiness, curriculum load), and (c) develop validated instruments aligned with core indicators such as interpretation, analysis, evaluation, and inference, including technology.

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