



Mathematical Thinking Research: A Bibliometric Study in 2016-2025 Based on Scopus Database

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Abstract

Mathematical thinking is a complex skill that urgently needs to be developed by students to support their readiness to face the Society 5.0 era. This era requires a super-smart society with reliable problem-solving abilities. Accordingly, this research provides a comprehensive bibliometric analysis of literature published in Scopus-indexed journals globally spanning a ten-year period. This research is a mapping study that forms part of a literature review. The analysis was conducted on 903 articles published between 2016 and 2025 from the Scopus database. The analysis was assisted by software, namely Bibliometrix and VOSviewer. The results were analyzed to map publication patterns, research affiliations, citation impact, authorship networks and thematic clusters. The number of documents increased significantly worldwide between 2016 and 2025. A total of 44.5% of the papers are in the social sciences. Universitas d'Alacant emerged as the most prolific institution, contributing the highest volume of publications. Concurrently, the United States represents the most prolific nation in terms of overall publication volume. The most cited document is a meta-analysis study by Mia C. Daucourt. Collaborations between countries and continents are frequent, particularly among the USA, China, Europe and Australia. Furthermore, the most prominent keywords associated with mathematical thinking include 'student', 'teacher', 'response', 'study', 'ability', 'skill', 'interaction' and 'noticing'. The findings provide a foundational reference for future mathematical thinking research by fostering international collaboration and integrating novel themes to advance scientific contributions.

Keywords: Bibliometric Study, Bibliometrix, Mathematical Thinking, Scopus, VOSViewer.

Introduction

The era of Society 5.0 was initiated by Japan and represents a concept of life that emphasizes social responsibility, improvement of quality of life and the discovery of new innovations, compared to the Industrial Revolution 4.0 era, which focuses more on technology (1). One of the challenges of this era is the need for a super-smart society capable of solving various social challenges by utilizing innovations developed during the Industrial Revolution 4.0, which are centered on technology (2). Amidst these global transformations, education is essential for preparing future generations and securing the advancement of the SDGs (Sustainable Development Goals) in 2030 (3). Thus, mathematics learning, as one component of education, also plays a role in equipping students with creative, innovative, productive, adaptive and competitive abilities, as well as enabling them to become reliable problem solvers.

Society 5.0 is built upon six fundamental dimensions, which include human-centered

innovation, continuous learning and development, strategic workforce planning, creative and innovative work environments, equality and inclusiveness, as well as ethics and sustainability (4). Mathematical thinking drives Society 5.0 educational reforms by integrating active learning, higher-order thinking and technology to prepare students for future challenges and support continuous learning and development (5). Rather than merely focusing on mathematical content, mathematical thinking is characterized as a cognitive style informed by the underlying operations, processes and dynamics of the discipline (6). Amid rapid global advancements, mathematical thinking empowers students to recognize when to apply their knowledge and skills, while simultaneously fostering the autonomy needed to pursue lifelong, independent learning (7). Modern frameworks move beyond restricting mathematical thinking to mere procedural knowledge; rather, they embrace a broader conceptualization that integrates critical

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thinking, creative problem-solving and metacognitive awareness. This holistic approach empowers students to navigate intricate challenges by effectively deploying their knowledge and skills (8). Most of the research limits mathematical thinking to problem-solving contexts (9). However, fully developing the skills and components of a student's mathematical thinking requires a foundation in deep, impactful and lasting learning. Consequently, this indicates that mathematical thinking extends well beyond problem-solving, comprising numerous dimensions that remain ripe for further empirical investigation.

Several studies on mathematical thinking have been conducted across various aspects over the past 10 years. Recent research, such as that conducted by examined how higher-level mathematical thinking skills are evaluated, demonstrating that educators utilize a variety of specialized tasks, tools and strategies to both measure and promote these cognitive abilities (10, 11). In a different aspect, the study investigated the instructional responses of novice mathematics educators when encountering high-potential moments of student mathematical thinking. Additionally, existing literature explores student mathematical thinking regarding the tree concept—a foundational element of graph theory—by integrating APOS (Actions, Processes, Objects and Schemas) theory with Tall's three worlds of mathematics (12). Given the many studies examining different aspects of mathematical thinking, there is a need for research mapping to identify new directions that support sustainable research.

Technological advances and the ease of accessing research data support researchers in conducting bibliometric analyses. Bibliometric analysis entails evaluating scientific productivity within a specific discipline or journal by applying statistical and numerical measures to various bibliometric parameters, including annual publication trends, prominent research themes, top-contributing institutions and journals, highly published authors, citation counts and high-frequency keywords (13). Through bibliometric analysis, researchers can trace the historical trajectory of a specific discipline and detect burgeoning areas of academic interest (14). Furthermore, bibliometric analysis provides researchers with a means to gauge the standing and impact of their own scholarly

contributions within the wider academic landscape (15). By analyzing document citation networks, co-authorship patterns and metrics of scholarly impact, investigators can extract meaningful insights into burgeoning research domains and shifting academic interests.

A bibliometric study on mathematical thinking was conducted, limiting Scopus data to authors affiliated with institutions in Indonesia between 2012 and 2022, with the analysis based entirely on visualization results from the Scopus database (16). Previous bibliometric studies on mathematical thinking trends relied on Google Scholar via Publish or Perish with VOSviewer in 2014-2024, but were strictly limited to elementary education and lacked the curated indexing quality of databases like Scopus (17). By capturing the complete publication record from the Scopus database over the last decade (2016–2025), this study provides a highly current and holistic landscape of mathematical thinking research. Rather than relying solely on the native, high-level visualization tools of the Scopus web platform, this study employs a rigorous bibliometric pipeline combining Bibliometrix and VOSviewer. This integration delivers a substantially richer analytical output and deeper insights into main information, yearly article distributions, subjects, affiliations, journal sources, citation patterns and treemaps, while uncovering complex academic structures through word clouds, authorship patterns, most cited documents, author/country collaboration networks and keyword co-occurrence relationships.

Methodology

This research is a literature review conducted as part of a mapping study. Conducted as a secondary study, a systematic mapping study categorizes and synthesizes existing primary research to deliver a comprehensive overview of a specific research domain (18). Meanwhile, bibliometric analysis involves examining documents and publication patterns based on bibliographic forms, number of publications, citations, trends, rankings and collaborations. For this study, bibliometric analysis was executed using data retrieved from the Scopus database. In this study, mathematical thinking is operationalized as a foundational competency for academic success, the core competency in mathematics education and

cognitive development that involves applying mathematical concepts, reasoning and methods to solve problems, generalize knowledge and represent ideas; it consists of mathematical attitudes, methods and ideas (8, 19, 20). To align the data retrieval with this conceptualization, the Scopus search strategy was specifically formulated using keywords that reflect these core dimensions (TITLE-ABS-KEY ("mathematical thinking" OR "thinking mathematically")). The documents were limited to the document type "Article" and the publication years 2016–2025, with subject

area restrictions of "Social Sciences", "Mathematics", "Psychology", "Computer Science", "Engineering", "Health" and "Multidisciplinary". The Scopus database for this study was accessed in May 2026; this retrieval date ensures coverage of the complete publication year for 2025 (January–December 2025). From this search, 903 research articles were obtained as metadata exported from Scopus in .csv (Microsoft Excel comma-delimited) and .ris (Research Information Systems) formats. Table 1 presents the specific keywords applied during the data retrieval phase.

Table 1: Detailed Scopus Search String and Operational Filters

Time Range	Scopus Search String	Result	Download Date
2016-2025	TITLE-ABS-KEY ("mathematical thinking" OR "thinking mathematically") AND PUBYEAR > 2015 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "MATH") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "ARTS") OR LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "HEAL") OR LIMIT-TO (SUBJAREA , "MULT"))	903	May 3, 2026

RStudio software, with the Bibliometrix (Biblioshiny) R package, was used for author, document, conceptual and intellectual structure analysis. Using metadata exported from Scopus, this program produced several outputs that were interpreted in this study, such as main information, most frequent words, most relevant authors, most relevant affiliations, treemaps, word clouds, co-occurrence network, thematic maps, thematics evolution, trending topics and collaboration world maps. VOSviewer was used to analyze themes in the Scopus metadata. Furthermore, this software assisted in analyzing conceptual structures and relationships between themes related to mathematical thinking. The researchers utilized network, overlay and density visualizations to present the results of the analysis. These results were interpreted and then elaborated with findings from Scopus and Bibliometrix to obtain an overview of research trends and mapping in the discussion section.

Results

The data on research in mathematical thinking obtained in this study are first presented through the results of analyses or plots from Scopus. Based on Figure 1, there is a clear increase in the number of documents during the periods 2016–2017, 2018–2020 and 2021–2022. Meanwhile, during 2017–2018 and 2020–2021, there was a decrease in the number of studies. From 2022 to 2024, the research trend tended to stagnate, followed by a significant increase in 2024–2025. Overall, within this time span, research on mathematical thinking experienced fluctuations; however, the number of documents increased significantly by the end of 2025, reaching nearly three times the number recorded in 2016. Documents by subject area from 2016-2025 show that 44.5% of the documents are in social sciences. Meanwhile, the second-highest number of documents comes from mathematics, at 23.8%, followed by psychology at 8.6%. Other fields with similar proportions include computer science, arts and humanities and engineering (all under 6%). Other closely represented fields include health professions, multidisciplinary studies, neuroscience and physics and astronomy (all under 2%).

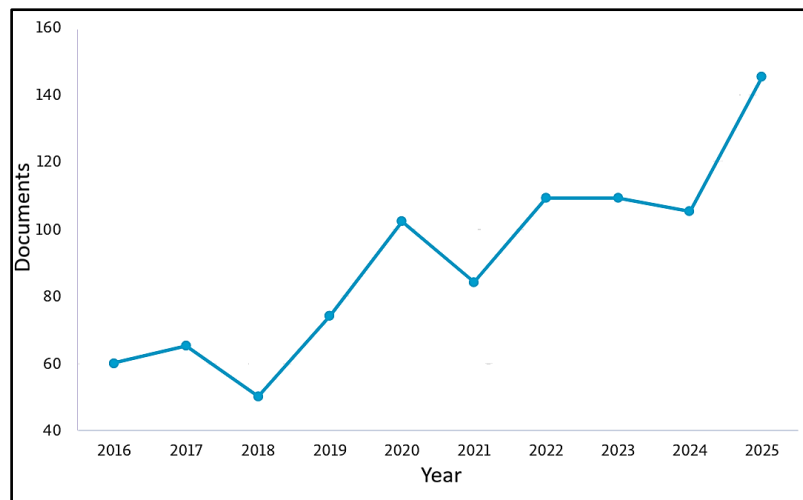


Figure 1: Documents by Year. Yearly Publication Growth from Scopus Data (n=903) from 2016-2025

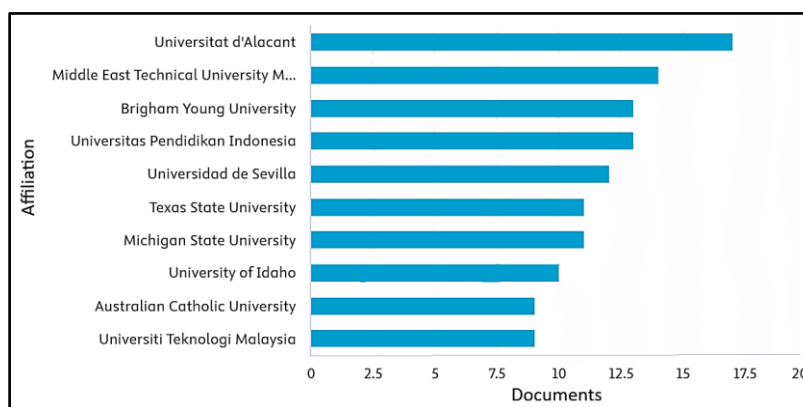


Figure 2: Documents by Affiliation. Distribution of Publications Related to Mathematical Thinking Across the Top 10 Affiliated Institutions from the Scopus Dataset in 2016-2025

Figure 2 describes documents by affiliation. Ten universities have the highest numbers of documents. Universitat d'Alacant ranks first with 17 documents. Middle East Technical University ranks second with 15 documents. Both Brigham Young University and Universitas Pendidikan Indonesia are tied for third place, each with 13 documents. The fourth plot from Scopus illustrates the top ten countries by document count as determined by the analysis. The United States has the highest number of documents, with 269 documents. Turkey ranks second with 71 documents. Indonesia and Spain rank third and fourth, with 70 and 56 documents, respectively. Australia, Colombia, China and Malaysia rank fifth to eighth, each with approximately 30–40 documents. The United Kingdom and Chile rank ninth and tenth, each with 27 documents. Figure 3 illustrates the annual document distribution across five primary journal sources.

Between 2016 and 2017, only the Journal of Mathematics Teacher Education experienced an increase, whereas other sources remained largely stagnant or declined. However, from 2017 to 2024, it underwent a period of decline and stagnation, before eventually rising sharply in 2024-2025. The analysis of source local impact by H-index reveals that three journals represent the core publication outlets in this domain. Journal of Mathematics Teacher Education leads with 16 publications, centering on the professional development continuum of mathematics educators. It is closely followed by ZDM – Mathematics Education ($N = 15$), which emphasizes critical analyses and the expansion of theoretical and empirical perspectives in mathematics education. Lastly, Eurasia Journal of Mathematics, Science and Technology Education ($N = 12$) provides coverage spanning mathematics, science, engineering, STEM and technology education.

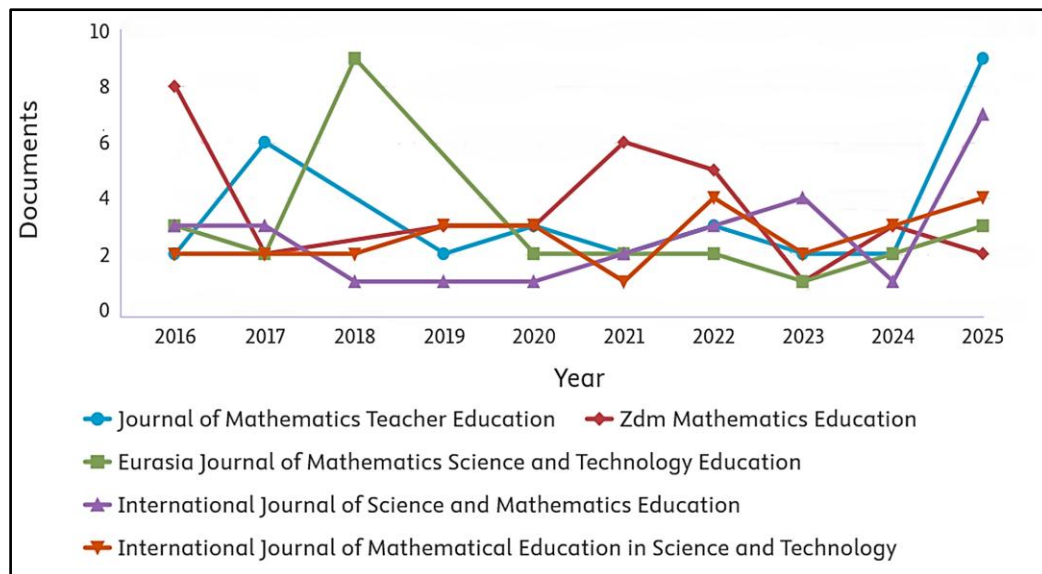


Figure 3: Documents by Source. Publication Trends of the Top 5 Source Journals on Mathematical Thinking. The Line Chart Illustrates the Annual Fluctuation in Document Output for the Most Prolific Scopus-Indexed Sources in a Ten-Year Period

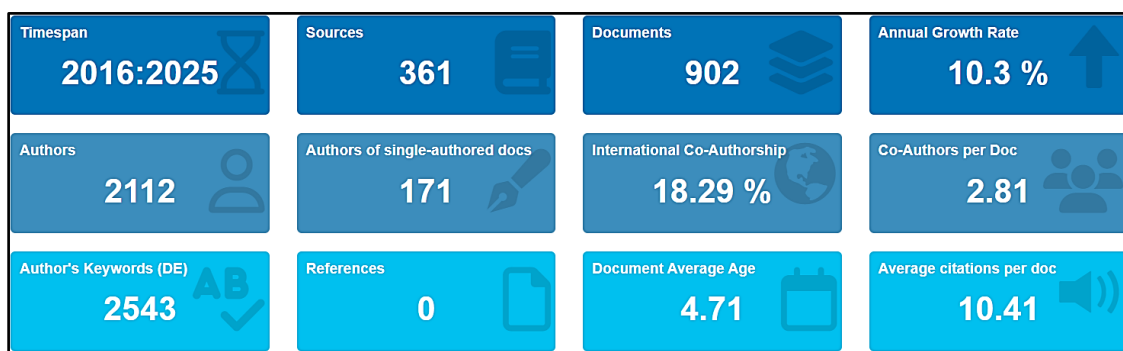


Figure 4: Main Information. Overview of the Analyzed Publication Dataset on Mathematical Thinking (Scopus, 2016-2025). The Summary Illustrates Key Bibliometric Parameters Using the Bibliometrix R Package

Figure 4 presents the main information from the database input into R using the Bibliometrix (Biblioshiny) software. The database contains 902 documents from 361 sources related to mathematical thinking. Another indicator is the annual growth rate, which reflects the increase in the number of documents compared to the previous year, recorded at 10.3%. Regarding authorship, 2,112 authors were involved in the study, with 171 authors contributing single-authored documents; 18.29% of the collaborations involved international co-authorship. A total of 2,543 keywords/themes are related to mathematical thinking. Another indicator is the average number of citations per document, which is 10.41. The top 10 most frequent words, treemap and word cloud are discussed. The keywords used in this analysis are author keywords, which are

selected by the authors to describe mathematical thinking. The keyword “mathematical thinking” appears most frequently, with 163 occurrences. The second and third most frequent keywords are “mathematics” and “mathematics education,” with 93 and 66 occurrences. In addition, “problem solving”, “human” and “teacher noticing” are also relevant to the theme. Finally, “computational thinking,” “learning,” and “students” are also frequent author keywords, appearing 25, 24 and 23 times, respectively. These keywords suggest a focus on analyzing the relationship between mathematical thinking and learning. The treemap provides information about the 50 author keywords, including their frequency of occurrence and their percentage relative to all keywords. The larger the box size, the greater the proportion of the keyword within the whole and vice versa. In

the treemap, the keyword “mathematical thinking” occupies 15% of the total area. The keywords “mathematics” and “mathematics education” occupy 8% and 6% of the total area, respectively.

Other keywords each account for between 1% and 4%. Author keywords can also be presented using a word cloud, as shown in Figure 5 below.

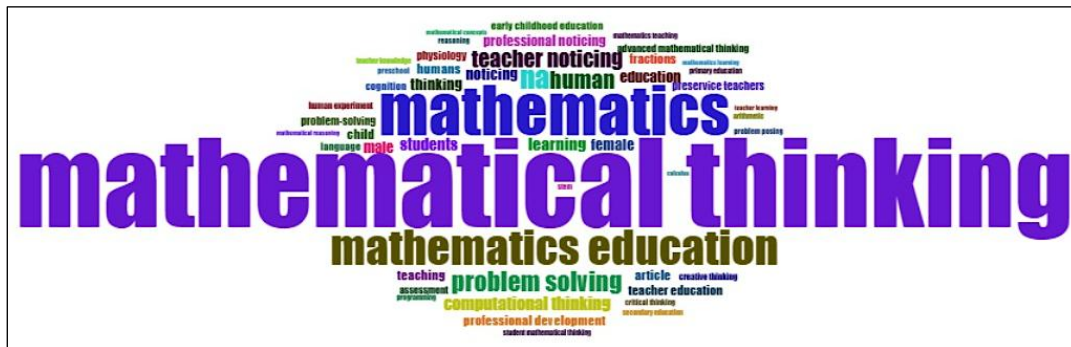


Figure 5: Word Cloud. Visualization of the Most Frequently Occurring Keywords in the Dataset

Data on the nine most relevant authors in mathematical thinking research include detailed information on the number of documents. Sanchez-Matamoros GM is the most relevant author, with eight documents. Fernandez C, Peterson BE and Stockero SL follow, each with seven documents, ranking second. In third place, Amador JM, Leatham KR, Osman S, Stewart S and Van Zoest LR each have six documents. The final position is occupied by Abdullah AH, with five documents. The results based on the most relevant affiliations show that Michigan State University and the University of California outperform other institutions with a total of 16 articles. Universitas Negeri Yogyakarta follows with 18 articles. Middle East Technical University and Universitas Pendi-

dikan Indonesia rank second with a total of 13 articles. Brigham Young University and Texas State University rank third and fourth, with 12 and 11 articles. Australian Catholic University, Universidad De Alicante, Universiti Teknologi Malaysia and University of Idaho each have 10 articles. Furthermore, the most cited country is the USA, with 3,419 citations. This is followed by Australia with 399 citations and Spain with 391 citations. Indonesia ranks fourth with 388 citations, followed by Turkey in fifth place with 382 citations. United Kingdom ranks sixth with 367 citations. Germany ranks seventh with 342 citations. The Netherlands, China and Canada rank eighth, ninth and tenth, with 251, 236 and 212 citations, respectively.

Table 2: Ten Most Globally Cited Documents

Rank	Authors	Years	Source	Total Citation	TC per Year	References
(1)	Mia C Daucourt	2021	Psychol Bull	205	34.17	(21)
(2)	Victoria R. Jacobs	2016	ZDM	147	13.36	(22)
(3)	Shari L. Stockero	2017	Teaching and Teacher Education	117	11.70	(23)
(4)	Joonkoo Park	2016	Journal of Experimental Child Psychology	116	10.55	(24)
(5)	Maria Kallia	2021	Research in Mathematics Education	110	18.33	(25)
(6)	Hwa, S. P	2018	Journal of Educational Technology and Society	106	11.78	(26)
(7)	Jodie Miller	2019	ZDM	95	11.88	(27)
(8)	Mustafa Cevikbas	2020	ZDM	93	13.29	(28)
(9)	Panagiotis Giannos	2023	JMIR Publication	91	22.75	(29)
(10)	Katie A Gilligan	2019	Developmental Science	89	11.13	(30)

Table 2 describes the most globally cited documents. There are ten documents identified as the most cited globally. In first place, with 205 citations, is Mia Daucourt’s 2021 article, which presents a meta-analysis of the mathematical

environment and mathematical achievement. Next is Victoria R. Jacobs's 2016 article "Responding to Children's Mathematical Thinking in the Moment: An Emerging Framework of Teaching Moves," with 147 citations. In third place is Shari L. Stockero,

with 117 citations, for the article, “Learning to notice important student mathematical thinking in complex classroom interactions”.

Figure 6 displays a co-word co-occurrence network depicting the structural relationships among key research themes in mathematical thinking. As the central hub of the network, "mathematical thinking" (represented by the largest red node) emerges as the dominant, recurring theme connecting core concepts such as problem-solving, mathematics education, STEM and creative and computational thinking. "Mathematics" (a large blue node) serves as a primary companion theme,

linking directly to elements like human cognition, reasoning, language and experimental learning. Peripheral clusters provide critical context: the technology cluster (green) highlights tools that aid in identifying and fostering students' mathematical thinking, while smaller nodes, including "student mathematical thinking", underscore the pivotal roles of pre-service teachers, teacher noticing and assessment. Collectively, these patterns confirm mathematical thinking as the core focus, supported by mathematics as a primary domain, with technology, pedagogy and assessment acting as key developmental pillars.

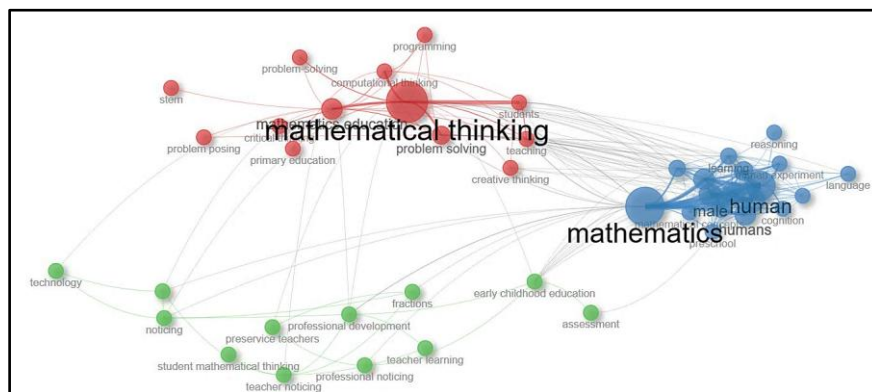


Figure 6: Co-occurrence Network. Keyword Co-occurrence Network Map of Publications Related to Mathematical Thinking Based on The Scopus Dataset

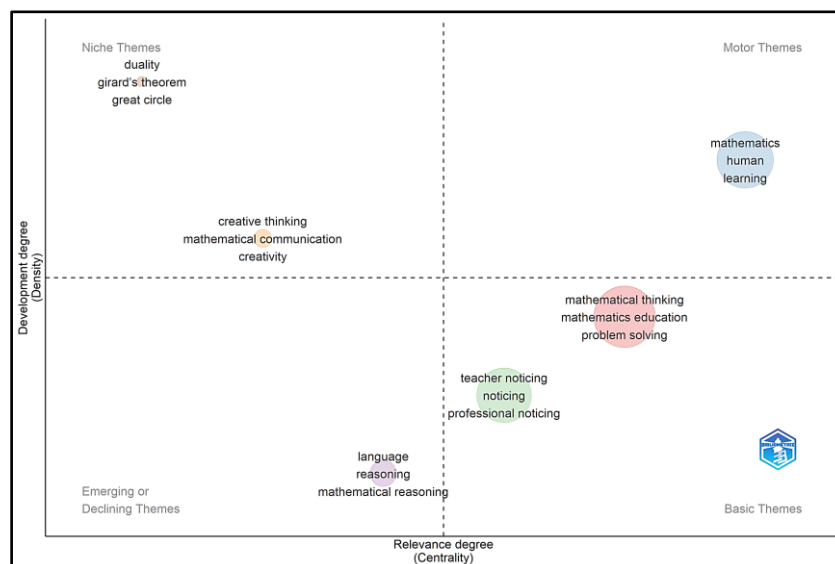


Figure 7: Thematic Maps. Four Quadrants in the Thematic Maps Depicting the Temporal Evolution of Research Themes in Mathematical Thinking

Figure 7 illustrates the thematic map. The thematic map illustrates a detailed overview of evolving research trends and publication trajectories within the field. These results are presented in four quadrants, each with an explanation. The first quadrant (motor themes) only shows mathematics,

human and learning. The second quadrant (niche themes) contains duality, Girard's theorem, the great circle, creative thinking, mathematical communication and creativity. Concurrently, the third quadrant—which captures emerging or declining themes—encompasses the concepts of

language, reasoning and mathematical reasoning. The fourth quadrant (basic themes) contains topics on mathematical thinking, mathematics education, problem-solving, teacher noticing, noti-

cing and professional noticing. The fourth quadrant describes research needs and possible future research trends.

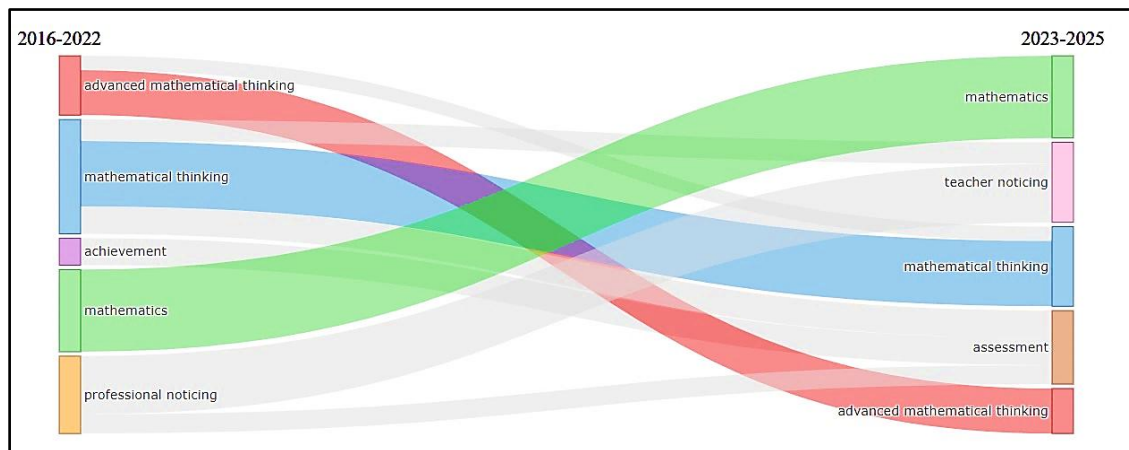


Figure 8: Thematic Evolution. Thematic Evolution of Research on Mathematical Thinking Across Two Time Slices (2016–2022 And 2023–2025)

Between 2016 and 2022, several shifts occurred in Author Keywords, as shown in Figure 8. Notably, the keyword "achievement" evolved into "assessment" during the 2023–2025 period. Likewise, "professional noticing" shifted toward "teacher noticing" and "assessment." This progression reflects a growing emphasis on evaluating achievement through systematic assessment, alongside a transition from a general focus on professional noticing to a more targeted focus on teacher practice and the assessment process. Furthermore, "advanced mathematical thinking" in the 2016–2022 period shifted slightly toward "mathematical thinking" in 2023–2025, signaling a broader research scope that encompasses mathematical thinking in a more holistic sense. The partial migration of keywords from "mathematical thinking" to "teacher noticing" and "assessment" during 2023–2025 highlights heightened attention to the teacher's role in identifying students' mathematical thinking and utilizing appropriate assessments to measure it. These shifts are expected to lay the foundation for further innovation in mathematical thinking research.

The next data to be analyzed are the trend topics from 2016 to 2025, as shown in Figure 9. Mathematical thinking peaked in 2022 with a term frequency of 160 and continued until 2024. Mathematical proof and problem solving also experienced an increasing trend from 2021 to the present. This indicates that mathematical proof and problem solving remains an emerging and expanding area of research. Meanwhile, research on professional noticing and mathematical communication appears to have stalled in 2022. The analysis shows strong collaboration networks among authors, such as Sanchez-Matamoros GM partnering with Fernandez C, Moreno M, Callejo De La Vega Mi and Valis J, as well as Peterson BE with Stockero SL, Van Zoest LR and Leatham KR. Based on the global collaboration map, this cooperation occurs not only within the same institution or country but also across continents—such as American authors collaborating with Asian authors (particularly from China and Korea), as well as Chinese and European authors partnering with Australian authors. This demonstrates that distance and geographical boundaries do not hinder the advancement of scientific knowledge.

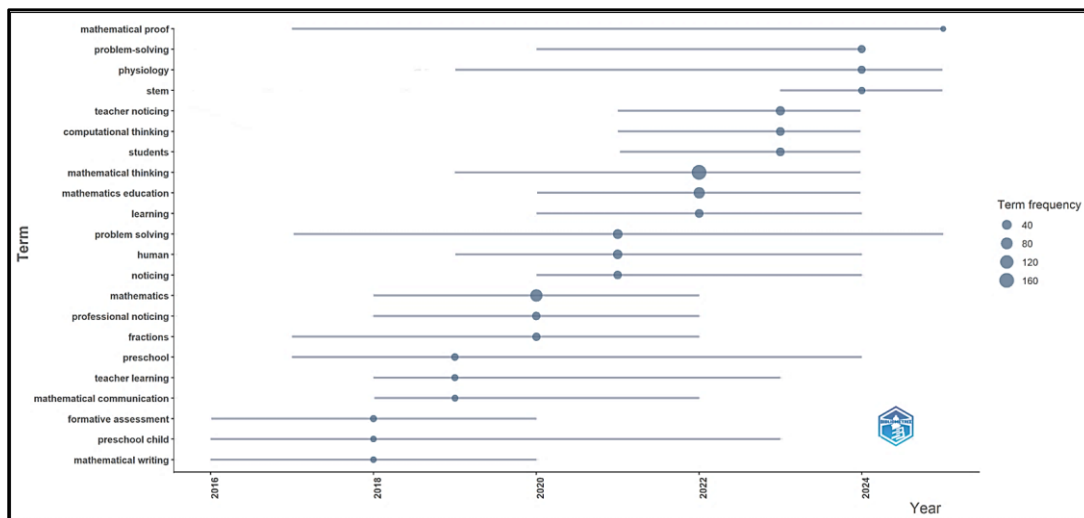


Figure 9: Trend Topics. Visualizing Topic Trajectories and Thematic Persistence over the 2016–2025 Period. Node Sizes Indicate the Relative Volume and Prominence of Each Topic Cluster

It can be seen from the VOSviewer visualization in Figure 10 below that the theme “mathematical thinking” is the most frequently occurring and is related to students, teacher, teaching, framework, practice, noticing, models and others. Meanwhile, the “students” theme is related to mathematical thinking, teacher, response, study, ability, skill and

others. The “teacher” theme is related to classroom, interaction, response, noticing and others. In other words, student mathematical thinking is closely related to classroom practices carried out by teachers in building interactions through the teaching process.

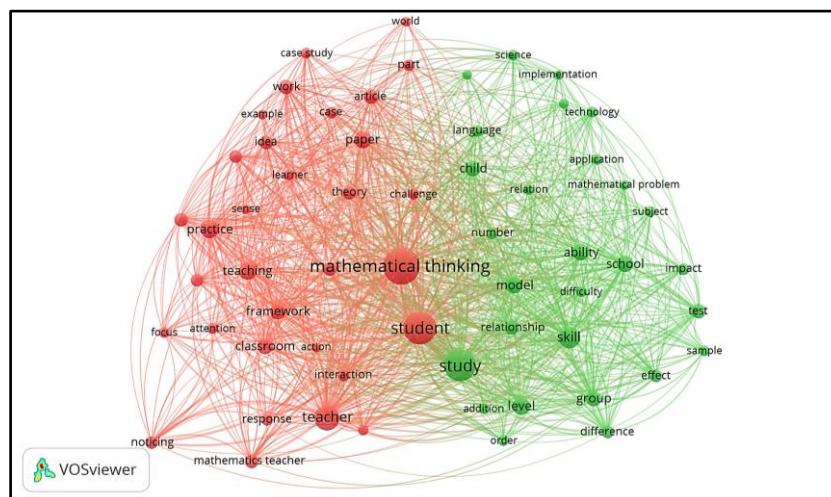


Figure 10: Network Visualization. Node Sizes Denote Item Weight; Link Thickness Reflects Interaction Strength and Colors Highlight Separate Analytical Clusters within the Dataset

Figure 11 shows that most articles focusing on mathematical thinking are in a transitional phase. Meanwhile, themes such as teaching, theory, child, language and number serve as the foundation of previous research topics. Emerging themes currently trending are indicated in yellow, including framework, interaction, implementation and responses. Studies on mathematical thinking can be linked to these emerging themes to offer novelty.

The VOSviewer analysis results then illustrate the density visualization (item density), as shown in Figure 12. The keywords “mathematical thinking”, “student” and study show their relationship to other themes or keywords, as indicated by item density. These related keywords include teacher, interaction, action, classroom, framework, teaching and practice. A higher keyword density indicates stronger connections among these keywords. The “mathematical thinking” theme

exhibits a high density indicated by bright colors, which means this theme frequently appears, is widely researched, or is extensively discussed

within the research dataset. Furthermore, this theme is visualized as a large node, signifying its substantial importance.

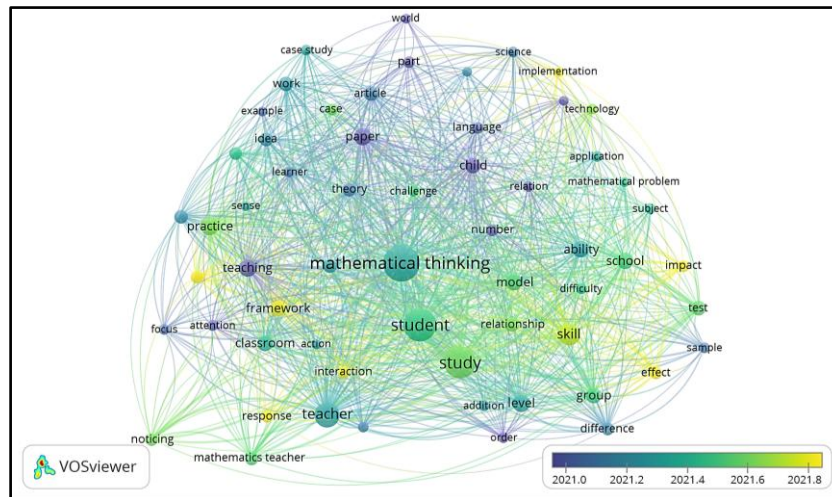


Figure 11: Overlay Visualization. Overlay Visualization Showing the Temporal Evolution of Keyword Co-Occurrence. Color Gradients Represent the Temporal Distribution (Average Publication Year) of Keywords, Highlighting Emerging Topics and Recent Analytical Trends

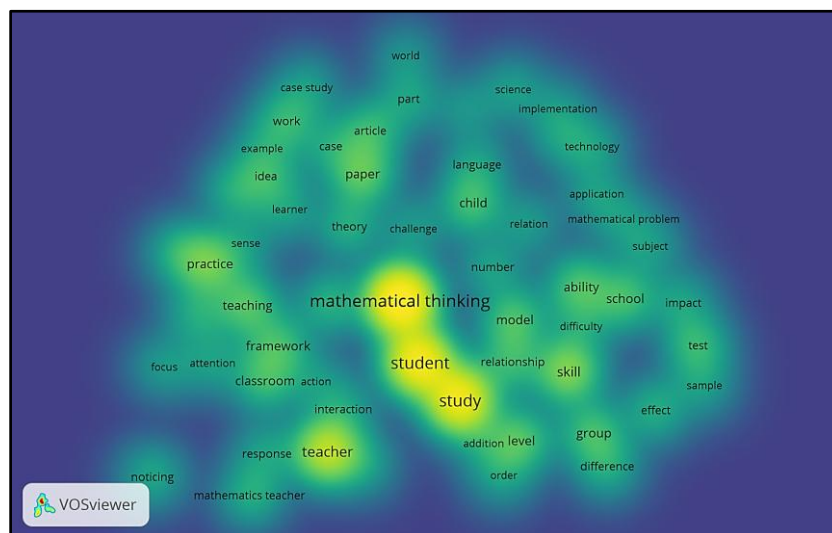


Figure 12: Density Visualization Generated by VOSviewer. Color Intensity and Brightness Correspond to the Density of Co-Occurring Terms, Highlighting Major Knowledge Centers and High-Frequency Research Clusters within the Dataset

Discussion

Mathematical thinking is a cognitive style driven by operations, processes and dynamics; however, it is frequently conflated with simply thinking about mathematics. However, mathematical thinking is not merely thinking about the subject of mathematics; therefore, the separation of content in classroom development is still less successful. Mathematical thinking is more than that; it is a foundational skill that extends beyond the mathematics classroom to include everyday problem solving, logical reasoning and decision making (31).

Mathematical thinking can be understood as the application of mathematical methods, techniques, concepts and conceptual frameworks to resolve problems both directly and indirectly (32). Unlike procedural fluency, which centers on executing algorithms and formulas quickly and accurately, mathematical thinking focuses on an analytical mindset for solving non-routine problems, like thinking "Why does this work?" and "What patterns lie beneath?" (9, 33). Operating as the foundational cognitive architect that transcends algorithmic execution, mathematical thinking

governs our approach to complex problem-solving while orchestrating the strategic deployment of essential mathematical tools, including reasoning, conjecturing, generalisation, abstraction, representation, creativity and modelling (8). In other words, mathematical thinking refers to a cognitive process that emphasizes understanding basic principles and applying them flexibly to new situations.

Given the importance of mathematical thinking, several researchers have conducted studies and published articles. Based on these articles, mapping and categorization can be developed to serve as a basis for future research. The Scopus graph shows fluctuations in the number of documents between 2016 and 2025, with a significant increase occurring between 2024 and 2025. Consistent with prior bibliometric research analyzing older datasets, our results confirm the publication slowdown experienced throughout 2020–2021 (16). This recent rise in publication frequency may indicate a resurging research trend, positioning mathematical thinking as an increasingly prominent topic in mathematics education studies.

Focusing on students' mathematical thinking is fundamental to effective teaching and learning (34). Furthermore, mathematical thinking can be fostered by creating a supportive learning environment through challenges, reflection and questioning (35). Moreover, the presence of learning environments as a key theme demonstrates that fields like social sciences are heavily engaged with mathematical thinking concepts. The subject area analysis reveals that the social sciences represent the primary context for 44.4% of prior research on mathematical thinking. Social development relies on cultivating mathematical thinking, a mindset that enables individuals to reason, innovate and contribute adaptively to a progressive society (36). Previous studies further examined mathematical thinking development by embedding cultural contexts, specifically utilizing ethnomathematics through folklore-based games during mathematics instruction (37). Meanwhile, other studies examine mathematical thinking in the fields of mathematics, psychology, computer science and others. Previous studies have investigated the relationship between mathematical thinking and psychological challenges involved in fostering mathematical thinking (38).

Furthermore, in relation to computer science, the didactic potential of using mobile technologies to develop mathematical thinking has been examined (39). Based on this, mathematical thinking can be studied across various research areas, each with its own novelty and relevance.

This study also found that Universitat d'Alacant produced the highest number of documents on mathematical thinking among universities. Fernandez *et al.* are researchers from Universitat d'Alacant who published the study that demonstrates how reflective contexts, like narrative writing, collaborative debates and feedback, enhance pre-service teachers' professional noticing of students' mathematical thinking (40). Furthermore, the United States of America is the country with the highest number of studies. Dick *et al.* from the USA studied predictions of cognitive dissonance and their interaction patterns, offering educators key insights to improve students' mathematical thinking noticing in technology-based learning (41).

The subsequent analysis examines articles based on their sources. However, not all of these journals focus exclusively on mathematical thinking. ZDM Mathematics Education had the highest number of articles on mathematical thinking-related learning in 2024–2025. Bibliometric analysis of the dataset revealed 903 documents from 357 sources related to mathematical thinking. Among the 2,066 authors identified, the low proportion of single authors [167] indicates that the majority of documents in this field involve collaborative writing efforts. In addition to addressing challenges, building academic partnerships through collaborative research can enrich research culture, strengthen research-based curricula and enable universities to remain relevant to society (42). Additionally, the substantial citation counts observed among these documents may reflect the ongoing prominence and relevance of mathematical thinking within the academic literature.

Based on the most frequent words, treemap and word cloud, "mathematical thinking" appears most frequently, with 158 occurrences. The second and third most frequent keywords are "mathematics" and "mathematics education." "Humans" is the fourth most frequent keyword, with 42 occurrences. Additionally, "teacher noticing" and "problem solving" are also related to the theme.

Studies on how pre-service teachers notice student mathematical thinking—specifically their ability to attend to, interpret and respond to it—highlight significant hurdles for designing future professional development programs (43). The way teachers cultivate classroom problem-solving and mathematical thinking was examined (44). The author highlights critical instructional actions and decisions, analyzes how personal beliefs shape these choices and discusses the resulting implications for both educators and learners.

Furthermore, an analysis was conducted to identify the most highly cited countries, with the United States of America ranking first. Several highly cited articles illustrate their importance and impact within the field. Daucourt's 2021 study, "The Home Math Environment and Math Achievement: A Meta-Analysis," is the most highly cited article related to mathematical thinking. This citation analysis helps identify future research trends and opportunities for further exploration.

It has been stated previously that research is a collaborative endeavor. This is also reflected in the analysis, which shows that authors collaborate across countries and continents. Collaborative research on mathematical thinking has been conducted by American researchers in collaboration with Asian authors, particularly from China and Korea. Furthermore, European authors have collaborated with Australian authors. While international collaboration is widely recognized as a cornerstone of an academic career, it is too frequently reduced to mere co-authorship, leaving a gap in research regarding actual perceptions and practices (45). Based on the VOSviewer visualization, the connection between mathematical thinking and these themes indicates that the literature frequently addresses factors associated with mathematical thinking, particularly in learning-environment contexts. For instance, prior research has explored pedagogical interactions, such as how teacher leaders prompt and respond to students' mathematical thinking in lessons. This serves as an example of efforts to examine mathematical thinking in relation to teachers, students, noticing and experiences.

Conclusion

This bibliometric study provides a comprehensive overview of the development of research on mathematical thinking based on publication trends

of Scopus-indexed articles. Data from the 2016–2025 period reveal fluctuations in publication volume, followed by a significant increase in 2024–2025. This trend indicates growing global recognition of the importance of mathematical thinking, both within mathematics education and in other fields. Furthermore, the analysis demonstrates that authors and institutional affiliations remain dominated by developed nations, such as the United States, Spain, Australia and China. Nevertheless, emerging contributions from developing countries like Indonesia and Malaysia signal an expansion of global participation. This growth is supported by cross-border co-authorships, which serve to enhance the impact of these studies toward shared progress. The main contribution of this study lies in mapping the evolution of themes and topical trends, highlighting a shift toward innovations designed to address contemporary issues. The expansion of mathematical thinking into themes such as assessment and teacher noticing points to innovations aimed at developing effective instruments to measure mathematical thinking abilities. In addition, these findings carry practical implications regarding the crucial role teachers play in noticing students' mathematical thinking to provide appropriate feedback. Consequently, there is a need for professional development programs focused on how teachers notice and facilitate the growth of mathematical thinking grounded in deep understanding. This study also offers a structured synthesis that enables educators, researchers and policymakers to grasp the research landscape and identify existing research gaps. However, this study has limitations as it relies solely on the Scopus database, which may not encompass all relevant publications. Furthermore, the dataset analysis was restricted to primary keywords and was not cross-linked with other specific terms such as technology, assessment, or learning. Future research should therefore expand the scope of data sources and employ more robust analytical methods.

Subsequent studies should also emphasize innovations that connect mathematical thinking with contextual scientific concepts, thereby contributing significantly to the advancement of mathematics education and other multidisciplinary domains.

Abbreviations

APOS: Actions, Processes, Objects and Schemas, SDGs: Sustainable Development Goals, STEM: Science, Technology, Engineering and Mathematics.

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Author Contributions

Arum Nur Wulandari: Conceptualization, Methodology, Investigation, Data Collection, Software Management, Data Curation, Resource Coordination, Writing-Original Draft, Preparing Visualizations, Validation, Editing, Marsigit: Conceptualization, Supervision, Formal Analysis, Supported Validation, Writing-Review, Kana Hidayati: Supervision, Result Validation, Critical Review.

Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this manuscript.

Data Availability

All data supporting the conclusions of this research are obtainable from the corresponding author upon reasonable inquiry.

Declaration of Artificial Intelligence

(AI) Assistance

During the preparation of this manuscript, the authors used Gemini AI solely for improving language clarity, generating wording suggestions and enhancing readability. On the other hand, the figures presented in the manuscript were directly generated using Scopus web, Biblioshiny (Bibliometrix R-Package) and VOSviewer. The authors independently reviewed, verified and are fully responsible for the accuracy and integrity of the content in this manuscript.

Ethics Approval

Ethical approval was not required for this study, as it did not involve human participants or animal subjects.

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