Jurnal Elementaria Edukasia
Volume 9, No. 2, Juni 2025, 113-128
DOI: 10.31949/jee.v9i2.13677

p-ISSN 2615-4625
e-ISSN 2655-0857

Trends in Research on Critical and Spatial Thinking Profiles in Matematics in Indonesia (2015-2025)

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Submitted: 2025-05-21
Revised: 2025-06-2
Accepted: 2025-06-20

ABSTRACT
The advancement of education in Indonesia has significantly emphasized the development of 21st-century skills, particularly in mathematics education. Critical thinking and spatial thinking are pivotal in enhancing problem-solving abilities, logical reasoning, and the practical application of mathematical concepts. Despite their importance, studies indicate that Indonesian students' proficiency in these areas remains low. This study aims to analyze research trends concerning critical and spatial thinking in Indonesian mathematics education from 2015 to 2025 through a bibliometric approach utilizing VOSviewer. Data were sourced from the Dimensions AI database and examined based on publication year, citation count, prolific authors, leading journals, and keyword novelty. Findings reveal a notable increase in publications post-2018, with a shift from descriptive studies to intervention-based research. Network visualizations and density maps highlight interconnections among themes such as critical thinking, spatial reasoning, geometry, and mathematical literacy. However, a research gap persists in integrating critical and spatial thinking within authentic learning contexts. This study underscores the necessity for educational policies and teacher training programs aligned with the Merdeka Curriculum, promoting research that is both contextual and applicable.
Keywords: *critical thinking; spatial thinking; bibliometric analysis; VOSviewer; mathematics; Indonesia.*

ABSTRAK
Perkembangan pendidikan di Indonesia menunjukkan peningkatan signifikan dalam penguatan keterampilan abad ke-21, khususnya dalam pembelajaran matematika. Dua keterampilan utama yang mendapat sorotan adalah berpikir kritis dan berpikir spasial karena peran strategisnya dalam pemecahan masalah, penalaran logis, dan penerapan konsep matematika dalam kehidupan nyata. Berbagai penelitian menunjukkan bahwa kemampuan berpikir kritis siswa Indonesia masih rendah, sementara penelitian mengenai berpikir spasial belum banyak dikembangkan, meskipun teori kecerdasan majemuk Gardner dan konstruktivisme Piaget-Inhelder telah lama menekankan

pentingnya aspek visual-spasial dalam pembelajaran matematika. Penelitian ini bertujuan untuk menganalisis tren dan profil penelitian berpikir kritis dan spasial dalam pendidikan matematika di Indonesia selama periode 2015–2025 melalui pendekatan bibliometrik menggunakan perangkat lunak VOSviewer. Data diperoleh dari basis data Dimensions AI dan dianalisis berdasarkan tahun publikasi, jumlah sitasi, penulis dan jurnal paling produktif, serta kebaruan kata kunci. Hasil analisis menunjukkan peningkatan publikasi signifikan sejak tahun 2018 dan pergeseran fokus dari studi deskriptif menuju studi intervensi dan eksperimental. Visualisasi jaringan dan peta densitas mengungkap keterkaitan antara tema-tema seperti critical thinking, spatial reasoning, geometry, dan mathematical literacy. Celah penelitian ditemukan pada minimnya eksplorasi integrasi berpikir kritis dan spasial dalam konteks pembelajaran nyata. Temuan ini diharapkan dapat menjadi dasar pengembangan kebijakan pendidikan dan pelatihan guru yang sejalan dengan Kurikulum Merdeka, serta mendorong riset lanjutan yang lebih kontekstual dan aplikatif.
Kata Kunci: berpikir kritis; berpikir spasial; bibliometrik; VOSviewer; matematika; Indonesia.

INTRODUCTION

The development of education in Indonesia shows a significant shift towards the enhancement of 21st-century skills, particularly in mathematics learning. Among these skills, critical thinking and spatial thinking are considered central, as they contribute to students' ability to solve problems, reason logically, and apply mathematical concepts in real-world contexts. The interplay between these two cognitive abilities is supported by several theoretical frameworks, such as Bloom's Taxonomy (revised by Anderson & Krathwohl) and Van Hiele's theory of geometric thinking, both of which emphasize the hierarchical and interconnected nature of thinking processes in mathematics. Spatial thinking supports visualization and geometric reasoning, which in turn reinforces analytical aspects of critical thinking.

Recent trends in mathematics education research in Indonesia highlight growing attention to students' high-order thinking processes. Studies increasingly emphasize the 4Cs creativity, critical thinking, communication, and collaboration as fundamental competencies for future learning (Sari & Maharani, 2024). Meanwhile, research shows that students' mathematical critical thinking remains low across education levels. Several studies have explored this from the perspective of gender and cognitive style (A'yun & Fatimah, 2025; Arvianto et al., 2025; Harahap et al., 2025; Saputri et al., 2024) , and identified linguistic and logical-mathematical intelligences as influencing factors (Panchal, 2023). Empirical findings also show that innovative models such as Treffinger, Problem-Based Learning (PBL), and generative learning have proven effective in improving critical thinking (Ayu Anggreani & Riduan Febriandi, 2023; Dasusmi et al., 2023; Merta, 2025). On the other hand, while not as extensively researched, spatial thinking is beginning to receive attention, especially in studies concerning geometry and visual-spatial intelligence. Students' spatial thinking profiles based on reflective cognitive styles, while other studies found that Van Hiele's theory and spatial reasoning significantly influence mathematical reasoning (Najma & Masduki, 2023; Purnamasari et al., 2024). Spatial abilities also enhance students' capacity to understand and remember visual representations, as highlighted (Salsabila et al., 2024), and affect their interest in geometri (Fitriyani et al., 2025; Sofakhiroh et al., 2024). PBL integrated with spatial reasoning is effective in strengthening

geometry problem-solving skills (Hidayatulloh et al., 2024; Suminar et al., 2024) . Moreover, spatial and critical thinking together positively impact broader competencies such as mathematical literacy, communication, and visual thinking (Ginting & Syahputra, 2024; Harris, 2023; Medina Herrera et al., 2024).

Despite the increasing attention to these domains, a clear gap persists. Most research tends to explore critical and spatial thinking separately, with limited studies examining their interconnection and integrated impact on learning. This gap affects classroom practices in Indonesia, where curriculum implementation often lacks the depth and scaffolding necessary to foster both types of thinking simultaneously. Additionally, although the Merdeka Belajar curriculum promotes higher-order thinking, teacher readiness and resource availability to support these competencies remain uneven, especially in under-resourced schools.

This study aims to map and analyze the research trends on critical and spatial thinking profiles in mathematics education in Indonesia from 2015 to 2025. Through bibliometric analysis using the Dimensions AI database and VOSviewer, this study examines: (1) the years with the most publications and citations, (2) the most productive and cited authors, (3) the most influential journals, and (4) keyword novelty analysis. Bibliometric studies, as emphasized (Romandoni et al., 2023; Suharjo, 2024; Syamsijulianto et al., 2024), are crucial for identifying research directions, potential collaborations, and gaps for further exploration.

This research shows that critical and spatial thinking are not only trending topics but also foundational for improving mathematics education in Indonesia. Therefore, findings from this analysis offer a strategic basis for aligning research with national education priorities, particularly in supporting the development of curriculum content, teacher training programs, and culturally relevant pedagogies. By integrating both cognitive skills into teaching practices, future research and policy efforts can more effectively contribute to developing students' comprehensive mathematical understanding.

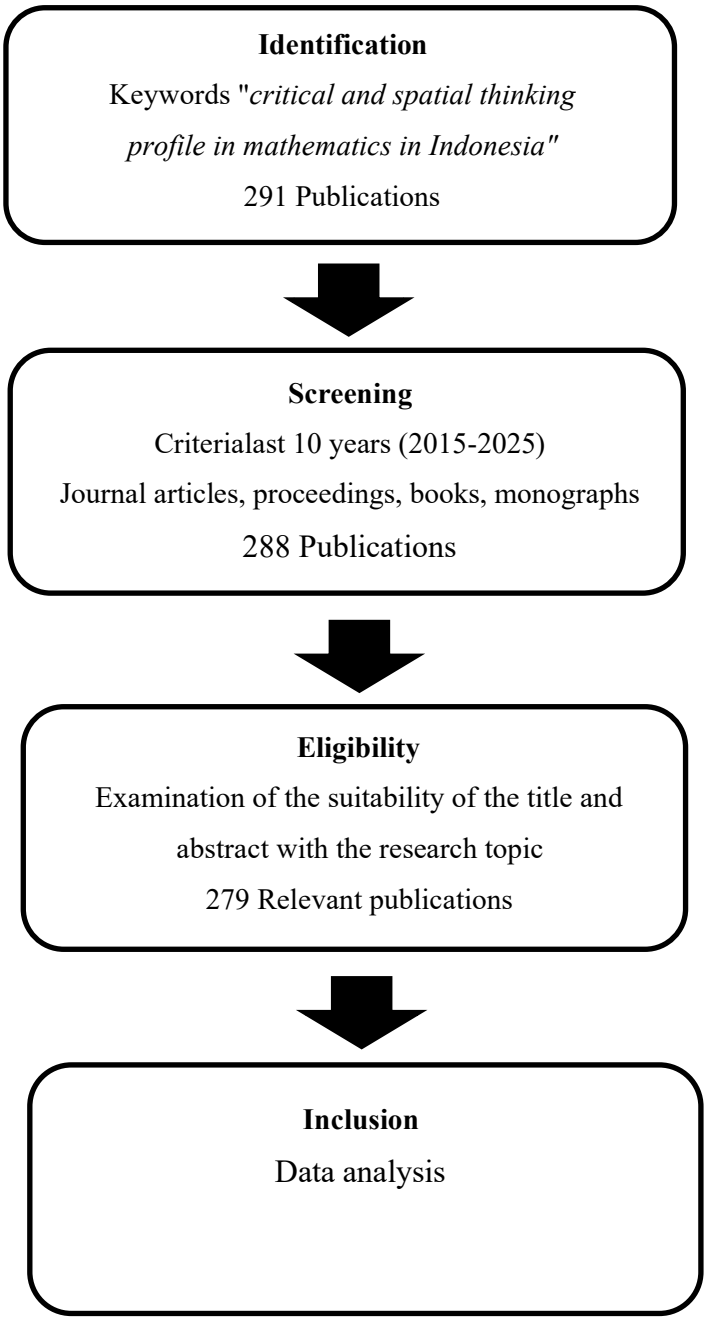
METHODS

Type and Design

The bibliometric approach used in this study is the descriptive analysis approach, (Alslan & Shiong, 2024; Wardani et al., 2024; Wulandari & Astutiningtyas, 2024). Descriptive analysis allows us to identify patterns and trends in scientific publications related to the understanding of critical and spatial thinking in mathematics in Indonesia. In this study, using the database Dimensions AI to collect and analyze publication data (Mayasari et al., 2024; Oueslati & Ayari, 2024). Dimensions AI is an artificial intelligence (AI) based platform designed to search, analyze, and visualize data from a variety of scientific sources, including journal articles, books, citations, research grants, clinical trials, and patents (Tjahjono et al., 2024).

The data collection process is carried out through four main stages. First**,** at the identification stage, we used the keyword "critical and spatial thinking profile in mathematics in Indonesia" and obtained 291 publications. Second**,** at the screening stage, we apply inclusion criteria, namely publication in the last 10 years (2015–2025) and only include journal articles, proceedings, monographs, books, and chapters. After this stage, there are 288 publications left.

Third, at the eligibility stage, we reviewed the suitability of the title and abstract with the research topic, resulting in 279 publications that were truly relevant. Fourth, publications that pass the feasibility stage are further analyzed at the inclusion stage. The analysis was carried out by exploring the trends of citations per year, citations per author, citations per journal, and identifying the novelty of the research. The data retrieval flow is presented in the following image.



Picture 1. Data Capture Flow

Data analysis is done with the help of VOSviewer and Microsoft Excel. VOSviewer used to visualize collaboration networks between researchers, analyze keywords, and perform other bibliometric mapping (Suhada & Yuadi, 2024). Meanwhile, Microsoft Excel Utilized for descriptive statistical analysis, including calculation of the number of publications per year, average citations, and publication trends presented in the form of graphs and tables. By combining these two softwares, researchers can present a comprehensive picture of research developments Critical and Spatial Thinking Profiles in Mathematics in Indonesia from 2015 to 2025.

Data and Data Sources

a. Data

The type of research data used in the form of descriptive quantitative bibliometric data related to the trend of critical and spatial thinking profiles in mathematics in Indonesia. The following is quantitative data from the critical and spatial thinking profiles in mathematics in Indonesia, collected from the Dimensions AI software.

Table 1. Trends in Citations of Critical and Spatial Thinking Research in Mathematics Education in Indonesia (2015–2025)

Year	Citation
2015	0
2016	0
2017	0
2018	4
2019	13
2020	42
2021	91
2022	100
2023	181
2024	206
2025	24
Total Citations	672

The above data is part of the quantitative data in the form of descriptive data used to analyze the data in this study. This research is quantitative until numerical data is produced. The table presented illustrates the trend in the number of citations received annually for a publication or scholarly work from 2015 to the projected year 2025. In the early years (2015–2017), the work had not yet received any citations—an expected condition for newly released publications or those that have not yet gained attention. A turning point occurred in 2018, when the work began to receive recognition with 4 citations. A significant increase followed in 2019, with 13 citations, and continued to rise sharply, peaking in 2024 with 206 citations.

This exponential growth indicates that the work gained substantial traction within the academic or scholarly community, reflecting increased visibility and impact. Interestingly, a notable projected decline is observed in 2025, with only 24 citations. This drop may be attributed to incomplete data for the current year (as of May 2025), or it could signal a shift in the work's relevance due to the emergence of new research or evolving academic trends. Overall, a total of 672 citations were recorded over the analyzed period, underscoring the significant influence of the publication throughout the examined timeframe.

b. Data Sources

The data source of this research was produced as a basis for finding the trend of critical and spatial thinking profiles in mathematics in Indonesia. This comes from a search in Dimensions AI. Thus, it can be said that the data source is part of the research pattern of critical and spatial thinking profiles in mathematics in Indonesia. Two hundred and seventy-nine articles from conferences in Indonesia, as well as leading scientific publications, have been collected. In addition, state data is used to generate up to 672 citations. Several criteria are used to narrow the search for this bibliographic data, the words "critical and spatial thinking profile in mathematics in Indonesia" as a title included in the Dimensions AI application as well as journals published for ten decades between 2015-2025. On Thursday, April 24, 2025, the process of the Dimensions AI device began. This is done to present a data search procedure for the Dimensions AI *device*.

Technical data collection

The data collection technique used in the bibliometric analysis of this study uses Dimensions AI, where the data in this analysis is filtered as baseline data to obtain relevant data based on reliable research findings related to ongoing research (Anwar et al., 2023). Application utilization techniques Dimensions AI It has the purpose of observing the results of the research carried out (Gunawan et al., 2023; Zaidan et al., 2023). In addition, there are several methods for conducting data collection using bibliometric analysis to examine Critical and Spatial Thinking Profiles in Mathematics in Indonesia. Once all the data collected is obtained, VosViewer used to organize data so that new data can be obtained.

Data analysis

To identify the pattern of critical and spatial thinking profiles in mathematics in Indonesia, bibliometric data analysis can be carried out following the four steps listed below for the collection of research data: (1) searching for publication data on the topic being searched using the Dimensions AI tool, (2) processing bibliometric data in Microsoft Excel to find relevant articles, including authors, titles, year of publication, and other details; (3) analyze bibliometric data mapping in publications; and (4) analyze Keyword Novelty using VosViewer. Only works published in the previous ten years, from 2015 to 2025, were used, and all data were obtained in April of that year.

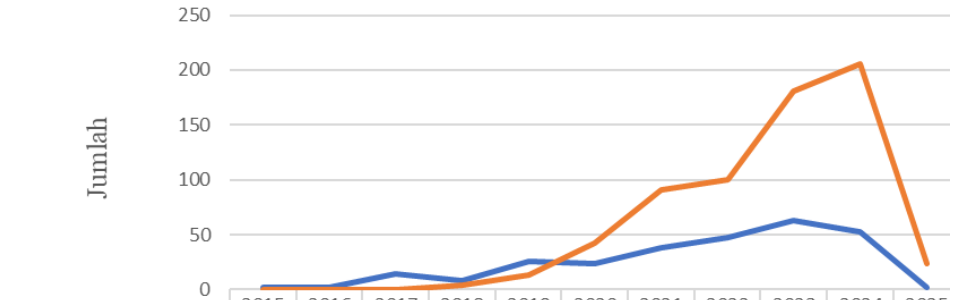
RESULTS AND DISCUSSION

This study identified as many as 279 publications obtained from the Dimensions AI database in the period 2015 - 2025. The collected publications include journal articles,

proceedings, books, and monographs, with a focus on critical and spatial thinking profiles on mathematics in Indonesia. Journal articles dominate with 247 publications. Followed by books that recorded 21 publications. Meanwhile, the rest consisted of monographs of 7 publications, proceedings of 3 publications and chapter 1 publication.

Most Published and Cited Years

The following is presented publication data and citations per year on the topic of critical and spatial thinking profiles in mathematics in Indonesia. This data is obtained from the analysis of Dimensions AI results presented in the Microsoft Excel table as follows.



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Publications (total)	2	2	14	8	26	24	38	47	63	53	2
Citations (total)	0	0	0	4	13	42	91	100	181	206	24

Picture 2. Publications and Citations Per Year

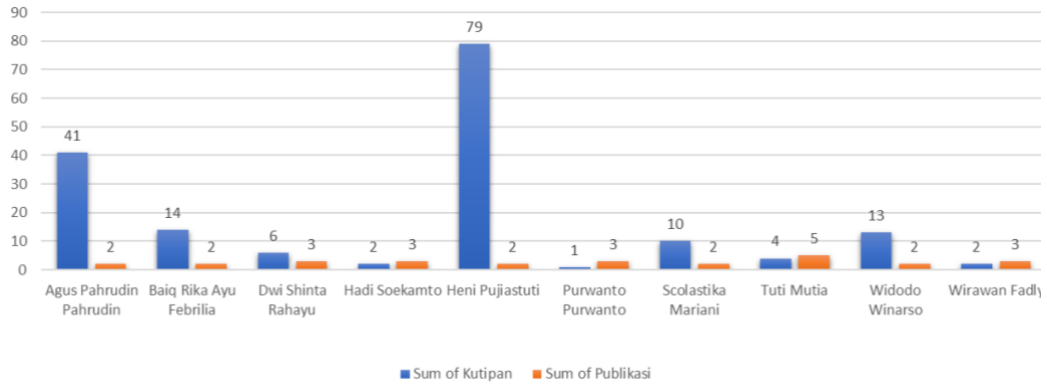
Based on the "Publications and Citations Per Year" graph which depicts 279 publications from the Dimensions AI database in the period 2015-2025, with a focus on critical and spatial thinking profiles in mathematics in Indonesia. From the results of the available data analysis, the number of research publications on critical and spatial thinking in mathematics in Indonesia has fluctuated from 2015 to 2025. In 2015 and 2016, the number of publications was still very low, i.e. only 2 publications per year, without any citations. Then, in 2017 there was a significant spike in the number of publications reaching 14, although it has not produced citations. However, in 2018, although the number of publications dropped to 8, there were 4 citations that showed the beginning of the influence of previous studies. A significant upward trend began to be seen since 2019, where the number of publications reached 26 with 13 citations. In the following year, 2020, the publication decreased slightly to 24, but the number of citations increased sharply to 42.

2021 and 2022 recorded higher spikes with 38 and 47 publications, respectively, as well as the number of citations that increased dramatically to 91 and 100. 2023 was the period with the highest number of publications, namely 63 publications, which was accompanied by an increase in the number of citations to 181. In 2024, the number of publications decreased slightly to 53, but citations continued to increase significantly to 206. Meanwhile, in 2025, the number of publications will again drop drastically to only 2, with the number of citations as many as 24. From this data, it can be concluded that research in this field has developed rapidly from 2017 to 2024, both in the number of publications and citations. However, a sharp decline

in the number of publications in 2025 could be an indication of changing research trends or other factors affecting the production of scientific publications in this field.

Most Productive and Widely Cited Author

In the academic world, the number of publications and citations are the two main factors in assessing a researcher's contribution and influence in the scientific community. Research productivity is measured based on the number of published works, while the number of citations reflects the extent to which the research is used or referenced by other academics. The following data shows a list of researchers who have been involved in studies on the critical and spatial thinking profiles of mathematics in Indonesia, focusing on the number of publications and citations they have obtained over the past few years. Through this analysis, the relationship between productivity and citation level can be found in determining the significance of a research in the academic world.



Picture 3. Most Productive and Widely Cited Author

Based on the results of the analysis, Tuti Mutia from the State University of Malang is the author with the highest number of publications, namely 5 publications, but only obtained 4 citations with an average of 0.80 citations per publication. This shows that despite its high productivity, its level of influence in the academic community is still relatively low. In contrast, there are authors with fewer publications who have higher citation rates, which indicates that productivity in the number of publications is not always directly proportional to the impact of the study. The author with the highest impact based on the number of citations was Heni Pujiastuti from Sultan Ageng Tirtayasa University, who had only 2 publications but **got** 79 citations, with an average of 39.50 citations per publication. Agus Pahrudin Pahrudin from Raden Intan State Islamic University Lampung also showed a similar pattern with 2 publications and 41 citations, resulting in an average of 20.50 citations per publication. This indicates that although the number of their publications is not as much as Tuti Mutia, the research they produce has a much greater influence among other academics.

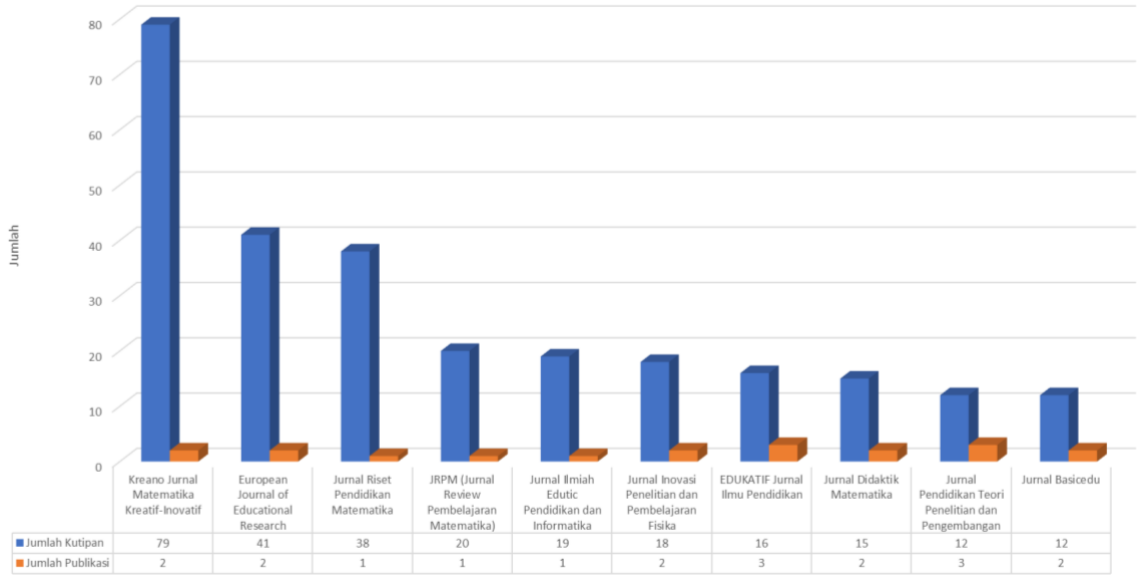
Furthermore, there are several authors who have 3 publications, such as Dwi Shinta Rahayu, Wirawan Fadly, Hadi Soekamto, and Purwanto Purwanto. Of this group, Dwi Shinta Rahayu stands out with 6 citations and an average of 2.00 citations per publication, indicating

that her research has greater appeal than her peers with the same number of publications. In addition, Scolastika Mariani with 2 publications and 10 citations and Widodo Winarso with 2 publications and 13 citations also show that they have a greater impact than some authors with more publications.

Overall, this analysis reveals that the number of publications is not the only indicator of academic success. Some authors with fewer publications actually have much higher citation rates, which suggests that the quality and relevance of research are more important than just productivity in the number of publications. Therefore, to assess one's academic impact, it is not enough to just look at the number of published works, but also how they are received and used by the rest of the scientific community.

Most Cited Journals

The higher the number of citations a journal receives, the greater its influence on the development of science, especially in the fields of education and science. Based on the data analyzed, there are ten journals with the highest number of citations that reflect the quality and attractiveness of published articles. The following analysis will further explore the relationship between the number of publications and citations, as well as the factors that can affect the visibility and significance of a journal in the academic community.



Picture 4. Widely Cited Journals

From the diagrams that have been presented, the Kreano Journal of Creative-Innovative Mathematics occupies the top position with 79 citations from 2 publications, which shows that this journal has a very high academic appeal despite its limited number of articles. The citation per publication ratio of 39.5 indicates that the articles published in it have significant weight in the study of creative and innovative mathematics. This phenomenon can be due to the strong quality of research, the broad relevance of the topic, or the author's collaboration with academics who have a wide network within the scientific community. In second place, the European Journal of Educational Research has 41 citations from 2 publications, with an average

of 20.5 citations per publication. This shows that this journal also has a considerable impact in the realm of educational research. Although the number of citations is lower than that of Kreano, the fairly high citation ratio indicates that the journal is well received in the academic community.

The Journal of Mathematics Education Research**,** which ranked third with 38 citations from just 1 publication, is an extreme example of how a single article can have a tremendous impact if the topic is relevant and the research methodology is robust. Furthermore, the JRPM (Journal of Mathematics Learning Review) has 20 citations from only 1 publication**,** which indicates that the published articles have great significance in the study of mathematics learning**.** The Edutic Scientific Journal of Education and Informatics with 19 citations from 1 publication also shows a similar pattern, where published articles are most likely to address current issues in educational technology and informatics that are relevant to many researchers. The Journal of Innovation in Physics Research and Learning has 18 citations from 2 publications, which although lower than other journals, still shows that the studies in this journal are quite taken into account in the field of physics education.

Interestingly, the Edukatif Journal of Education has 16 citations with 3 publications**,** making it the only journal on this list that has more than 2 publications**.** This shows that although its citation per publication ratio (**5.33**) is lower than other journals on this list, Edukaatif still has good competitiveness in the academic community with more publications receiving attention. Meanwhile, the Didactic Journal of Mathematics and the Journal of Basicedu, with 15 and 12 citations from 2 publications, respectively, have a fairly high appeal in educational and mathematical research.

Overall, it can be concluded from this table that a high number of citations is not always directly proportional to the number of publications**.** Some journals with only 1 or 2 publications are able to collect a lot of citations, which shows that the quality of the article **is** more influential than the quantity. Journals that have a high citation-per-publication ratio are more likely to have articles that are highly relevant to current research trends, or contain studies that have strong methodologies and contributions. In addition, journals with a higher number of publications but still included in this list, such as the Edukatif Journal of Educational Sciences, show that productivity can still coexist with a high citation rate. This indicates that the combination of quantity and quality can be the optimal strategy for journals to increase their academic visibility and influence.

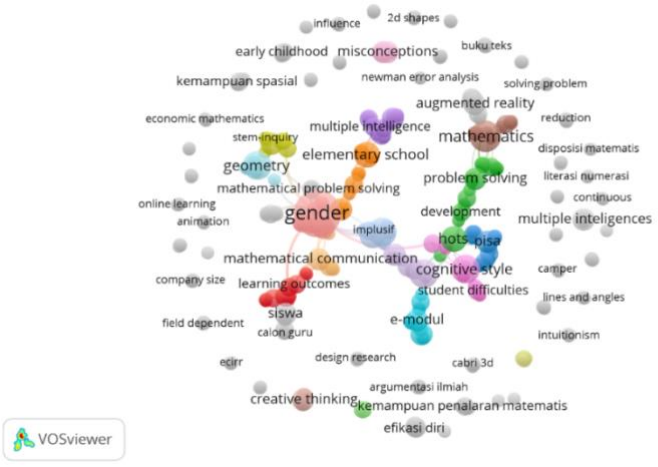
Novelty Keyword Analysis

The VOSviewer application successfully maps several articles to make it easier researchers in reducing articles based on specific items (Bukar et al., 2023). VOSviewer is used to view data and statistics from the sorting process while conducting data analysis through bibliometrics and mapping (Syamsijulianto et al., 2024). The mapping visualization in this study is analyzed with 3 schemes, namely network visualization (Network Visualization), overlay visualization (Overlay visualization), and density visualization (Density Visualization) (van Eck & Waltman, 2010). The terms can be visualized in the form of networks and important terms in the scientific literature (Sidiq, 2019). As can be seen from

Figure 4, Green-Armytage (2020) argues that some circles have different colors, circle sizes, and labels that are connected by the lines (Syamsijulianto et al., 2024). Labeled circle size show Positive correlation between Keyword Novelty. From these results Research related to research trends on critical and spatial thinking profiles in mathematics is divided into 6 clusters. The results of the literature mapping using VOSviewer shows that the six clusters formed do not stand alone, but are interconnected with each other. The relationship is seen through the connecting lines between the circles in the network visualization.

Cluster 1 (red) which focuses on gender, mathematical communication, and learning outcomes shows a close relationship with Cluster 2 (green) which examines cognitive style and student difficulties. This interconnectedness reflects that individual student factors such as gender and cognitive style affect math learning outcomes and mathematical communication skills. Meanwhile, Cluster 2 (green) is also connected to Cluster 3 (light blue), which discusses problem solving and mathematics. This shows that cognitive styles and learning difficulties also affect students' mathematical problem-solving abilities, so the development of learning media such as e-modules is important to optimize these skills.

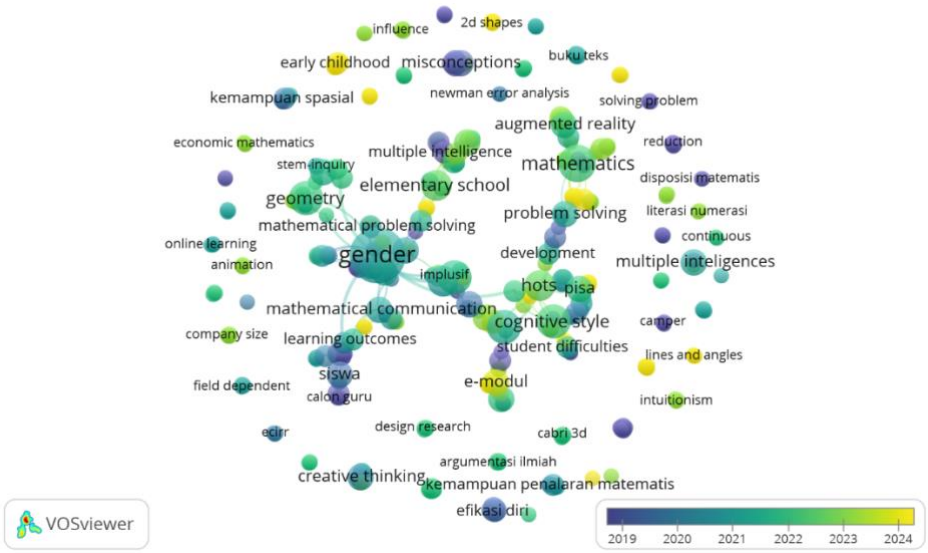
Cluster 4 (yellow) which focuses on elementary school, multiple intelligence, and inquiry intersects with Cluster 5 (purple) which raises the theme of misconceptions and early childhood. This interconnectedness emphasizes the importance of a learning approach that pays attention to the intellectual characteristics of students from an early age, to prevent misconceptions, especially in the areas of geometry and spatial ability. On the other hand, Cluster 6 (brown) which discusses creative thinking, mathematical reasoning skills, and self-efficacy shows a relationship with other clusters, especially Cluster 3 (light blue) and Cluster 4 (yellow). This relationship indicates that creative thinking and reasoning skills cannot be separated from mastering problem-solving skills and developing students' potential through a learning model based on multiple intelligence.



Picture 5. Visualization of Critical and Spatial Thinking Profile Trend Network in Mathematics in Indonesia

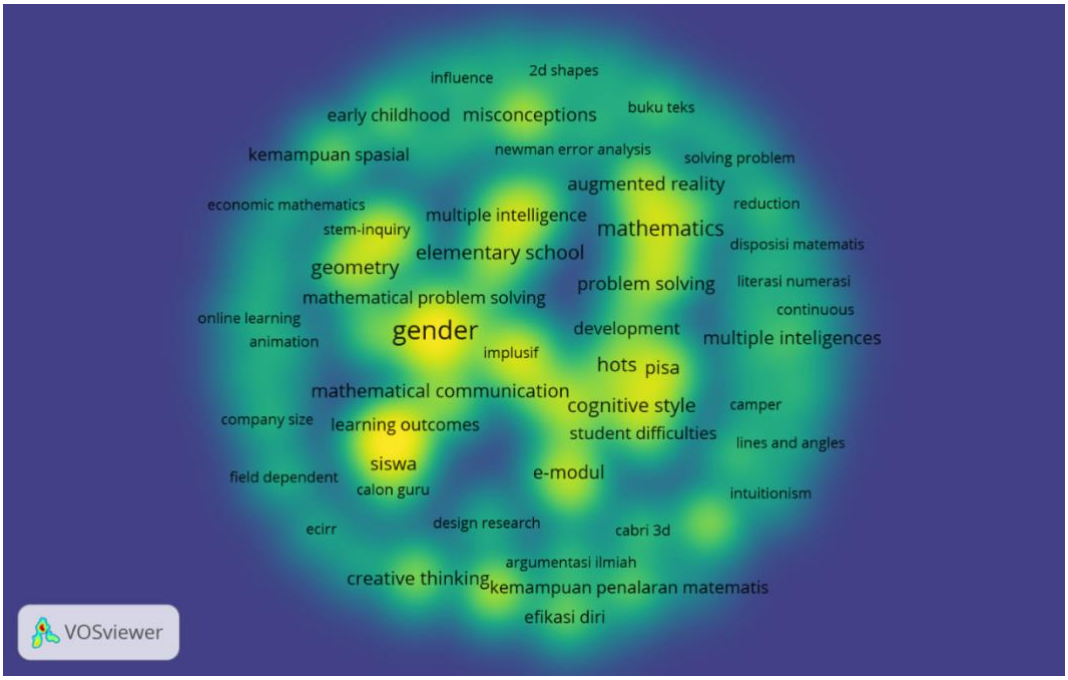
Furthermore, the visualization of the overlay shown in Figure 5 shows that the research on the trend of critical and spatial thinking profiles in mathematics in Indonesia was conducted from 2015 to 2025. The image above is the result of overlay visualization using VOSviewer software on studies related to critical and spatial thinking profiles in mathematics learning in Indonesia. In this visualization, key terms are still visualized in the form of a circle, but given additional color gradations based on the year of publication. The color scale used is in the range of 2019 to 2024, with Dark blue indicates more published research around 2019-2020, Green indicates publications around 2021-2022, Yellow color indicates more recent research, i.e. around 2023-2024.

The interpretation of images with keywords such as gender, mathematical communication, problem solving, and e-modules is dominated by green to yellow, indicating that these themes are quite new topics and have been increasingly researched in the last 2-3 years. Meanwhile, terms such as misconceptions, early childhood, spatial ability, and multiple intelligences tend to be blue or dark green, indicating that these topics have been widely researched before, especially before 2021. The relationships between terms are still depicted through connecting lines, indicating the relevance of the topics even though the research was conducted in different years. This visualization shows that there is a shift in research focus from basic aspects (such as misconceptions and compound intelligence) to more innovative themes such as the development of e-modules, the application of augmented reality, and the integration of HOTS and PISA approaches in mathematics learning in Indonesia. In addition, the latest trends also show greater attention to individual student variables such as cognitive style, gender, and self-efficacy in supporting critical and spatial thinking skills.



Picture 6. Visualization of Overlay Trends in Critical and Spatial Thinking Profiles in Mathematics in Indonesia

The results of density visualization using VOSviewer software on studies related to critical and spatial thinking profiles in mathematics in Indonesia. In this visualization, key terms are visualized based on their frequency level and relevance in the literature. The color scheme used shows areas with high and low density. The bright yellow color indicates an area with a high level of density, meaning that the term appears frequently and has a strong association with many other terms. The green color indicates a moderate level of density. Purplish-blue indicates low density, meaning the term appears less frequently or is weakly related. The terms gender, mathematics, problem solving, mathematical communication, cognitive style, and hot pisa appear in bright yellow zones, indicating that these terms have a high frequency of occurrence and a strong connection in related studies. Other terms such as geometry, elementary school, multiple intelligences, e-modules, and creative thinking are in the green area, indicating that they also appear quite often but not as high as the term in the yellow center. Terms in the blue area, such as economic mathematics, field dependent, and intuitionism, are terms with lower occurrence and relevance than other terms. This visualization clarifies the main focus in mathematical critical and spatial thinking research, namely on individual aspects of students (such as gender and cognitive style), innovative learning approaches (such as HOTS-PISA and e-modules), and strengthening problem solving and mathematical communication skills. This indicates that future research has the potential to further deepen these themes, especially in local contexts and technology-based learning innovations.



Picture 7. Visualization of Density Trends in Critical and Spatial Thinking Profiles in Mathematics in Indonesia

These three visualization schemes complement each other to provide a comprehensive overview of the map of critical and spatial thinking research in Indonesia. Network visualization helps to understand the structure of the clister, overlay visualization shows the temporal development of this field, and density visualization clarifies the areas with the highest concentration of research. Although this study provides a fairly comprehensive overview of research trends, several limitations should be acknowledged. First, the analysis relied solely on one database, namely Dimensions AI, which means relevant publications indexed in other databases such as Scopus, Web of Science, or Google Scholar may not have been captured. Second, the publication search and selection strategy based on keywords may introduce bias or errors in the data filtering process. Third, data from the year 2025 may not yet be fully indexed, so interpretations regarding trends in that year should be made with caution.

Based on the analysis results, several recommendations can be made for future research. First, researchers are encouraged to utilize a broader range of databases to obtain a more comprehensive dataset. Second, integration between bibliometric findings and in depth qualitative reviews is necessary to capture a more holistic view of theoretical and practical dynamics. Third, expanding research directions into educational technology fields such as the use of AI, AR, and gamification to enhance critical and spatial thinking offers great potential. Lastly, it is important to continuously link research findings to the local educational context, including curriculum, educational policy, and cultural values in Indonesia, to ensure that the research outcomes are more applicable and have a direct impact on educational practice.

CONCLUSION

This bibliometric analysis of research from 2015 to 2025 reveals that studies on critical and spatial thinking in mathematics education in Indonesia have grown significantly, with a strong focus on elementary education, problem-solving, cognitive styles, and the integration of digital learning tools such as e-modules and augmented reality. Key terms like HOTS, PISA, and mathematical reasoning reflect a national emphasis on advancing higher-order thinking skills.

Practically, these findings highlight the importance of integrating critical and spatial thinking into the mathematics curriculum to better equip students with 21st-century competencies. However, the study is limited by its reliance on a single database (Dimensions AI), which may exclude relevant research indexed elsewhere. Additionally, the use of keyword-based filtering may introduce selection bias, and data from 2025 may still be incomplete.

Future research should explore broader databases, incorporate qualitative insights, and investigate how emerging technologies such as AI and gamification can further enhance students' thinking skills. There is also a pressing need to align research outcomes with local educational contexts, particularly curriculum development and culturally relevant pedagogy in Indonesian schools.

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