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Bibliometrics Analysis of the Development of Research on Spatial Thinking in Elementary School: Global Trends 2015-2025

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Abstract: This study aims to examine research trends on the development of spatial thinking at the elementary school level through a comprehensive bibliometric analysis. Spatial thinking is recognized as a fundamental cognitive ability that supports students' understanding of mathematics, science, geography, and problem-solving in everyday contexts. Despite its importance, research specifically addressing spatial thinking in elementary education remains limited. The study employed a bibliometric approach to analyze publications related to spatial thinking in elementary schools. The research process consisted of three main stages: data collection, data identification, and data visualization. Data were retrieved and analyzed using the Publish or Perish software, while VOSviewer was utilized to map research networks, keyword co-occurrences, and publication trends. The findings revealed that a total of 420 articles on spatial thinking were published between 2015 and 2025, indicating a growing academic interest in this field over the past decade. Furthermore, the analysis identified the ten most highly cited articles related to spatial thinking. However, only one of these highly cited studies specifically focused on spatial thinking in the context of elementary education, whereas the remaining studies primarily examined secondary, higher, or general educational settings. This imbalance highlights a significant research gap and suggests that spatial thinking at the elementary school level has not yet received sufficient scholarly attention.

Keywords: Spatial Thinking, Elementary School, Bibliometrics.

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INTRODUCTION

Spatial thinking is a fundamental cognitive ability that enables individuals or groups to understand, represent, visualize, and manipulate information about space and the spatial relationships between objects (Lokollo et al., 2024). This ability serves as a strong predictor in the development of STEM (science, technology, engineering, mathematics) learning approaches (Arisha, 2023). Longitudinal research indicates that spatial thinking makes a significant contribution to academic achievement in mathematics and science, even surpassing the contribution of verbal ability (Casey et al., 2015; Atit et al., 2020). Moreover, spatial thinking is a transferable skill that can be learned and improved through structured and systematic instruction, making it a strategic target for development in the digital era and the industrial revolution (Hawes et al., 2017). Furthermore, spatial thinking makes a unique contribution to the understanding of geometry, measurement, and algebra, accounting for an explained variance of 20-30% in students' mathematical performance (Hawes & Ansari, 2020).

Although spatial thinking has been well documented and accommodated in the literature, the reality in the field is concerning, particularly at the elementary school level (Prasmono et al., 2023). Instruction in elementary schools remains heavily focused on numerical and verbal aspects, while the spatial dimension is neglected (Mathewson, 1999). Schools should specifically be able to develop spatial abilities, such as 3D object manipulation and mental rotation (Newcombe, 2017). The curriculum has not been able to accommodate spatial understanding in a reflective and planned manner, and teachers still lack a sufficient understanding of the essence of spatial thinking (Oktavianto, 2022). Research conducted in elementary schools found that only 68% of students possessed spatial thinking abilities below the level appropriate for their age (Faridah et al., 2024). Meanwhile, in Indonesia, 74% of students have low spatial ability, particularly in the aspects of mental rotation, spatial orientation, and spatial visualization (Cholilah, 2023). These conditions arise partly because education in Indonesia still relies on routine, low-order questions. Over the past decade, 587 journal publications have appeared, yet only 12% focused on spatial thinking for elementary school children (Bednarz, 2019).

The gap between the urgency and the reality of spatial thinking creates a paradox in education: on one hand, spatial thinking is recognized as a critical skill for mathematical reasoning, complex problem solving, and success in the digital era, yet on

the other hand this ability is not adequately facilitated in elementary school instructional practice (Herman, 2024). This paradox is compounded by the fragmentation of knowledge within the spatial thinking research literature, where despite the rapid increase in the number of publications over the past decade, no comprehensive mapping has yet systematically identified the trends, focus, and direction of research development. The absence of a big picture of the spatial thinking research landscape makes it difficult to identify research gaps, evidence-based best practices, and research priorities responsive to the practical need to improve elementary school students' spatial thinking ability (Agni, 2025). Furthermore, there is an indication of a disconnect between the volume of published research and its practical implementation in classrooms, where the majority of studies remain basic research with limited ecological validity for real learning contexts.

Given this gap, a bibliometric analysis of the development of spatial thinking research becomes highly urgent as a strategic step to map the state of the art of the field, identify the strengths and weaknesses within the existing body of knowledge, and guide a more impactful future research agenda (Tandjung, 2023). This study aims to examine trends in the development of spatial thinking ability at the elementary school level (Zalfa, 2023). The bibliometric approach used in this study is based on spatial mapping analysis with the assistance of Publish or Perish and VOSviewer. The search strategy drew on the Google Scholar database, using article titles as the guiding criterion. The search term used was "spatial thinking in elementary school." Bibliometric analysis has recently proven useful in examining research breakthroughs and phenomena. It also helps provide an up-to-date understanding of the boundaries and trends of a field.

RESEARCH METHOD

This study used a statistical method known as bibliometric mapping to understand how the literature on spatial thinking in elementary school has developed from 2015 to 2025 (Bazilova, 2025).

Bibliometric analysis is used to evaluate a broad body of scientific data within a specific domain, particularly in identifying patterns and trends in research on spatial thinking ability at the elementary education level (De Queiroz, 2021). This method helps analyze global publication trends related to spatial thinking. It examines the most cited studies, leading authors, productive journals, institutions, countries, and frequently used

keywords in order to understand the development of the spatial thinking field in elementary schools.

The application of the bibliometric method can enhance the visibility and impact of research, while also providing a comprehensive mapping of the spatial thinking research landscape at the elementary education level (Irawan et al., 2024). Therefore, conducting an in-depth bibliometric study provides a holistic perspective for identifying research gaps in spatial thinking in elementary school, generating new ideas for developing spatial-ability-based learning strategies, and strengthening the position and contribution within the relevant scientific context of elementary education.

RESULTS AND DISCUSSION

1. Development of Spatial Thinking Research in Elementary School, 2015-2025

Table 1 presents the annual report on research on spatial thinking in elementary school published in national and international journals. Based on this data, it is known that over the past ten years there were 420 documents in total. The breakdown of the number of research documents on spatial thinking in elementary school is as follows: 27 documents in 2015, 37 in 2016, 37 in 2017, 58 in 2018, 48 in 2019, 67 in 2020 (the peak year), 53 in 2021, 44 in 2022, 24 in 2023, 22 in 2024, and 3 in 2025.

Table 1. Annual Research Report on "Spatial Thinking in Elementary School"

Year	Number of Publications	Percentage (%)
2015	27	6.428
2016	37	8.809
2017	37	8.809
2018	58	13.809
2019	48	11.428
2020	67	15.952
2021	53	12.619
2022	44	10.476
2023	24	5.714
2024	22	5.238
2025	3	0.714
TOTAL	420	100

Based on the number of studies published each year, it is evident that publications on spatial thinking in elementary school have declined since 2021-2025. Figure 1 more clearly illustrates the annual decline in the number of publications over recent years. Over the past ten years, the highest number of studies was recorded in 2020 (67 documents), while the lowest was recorded in 2025 (3 documents). From 2020 to 2021 there was a decrease of 14 documents, while the sharpest decline occurred between 2022 and 2023,

with a decrease of 20 documents, followed by a decrease of 19 documents between 2024 and 2025.

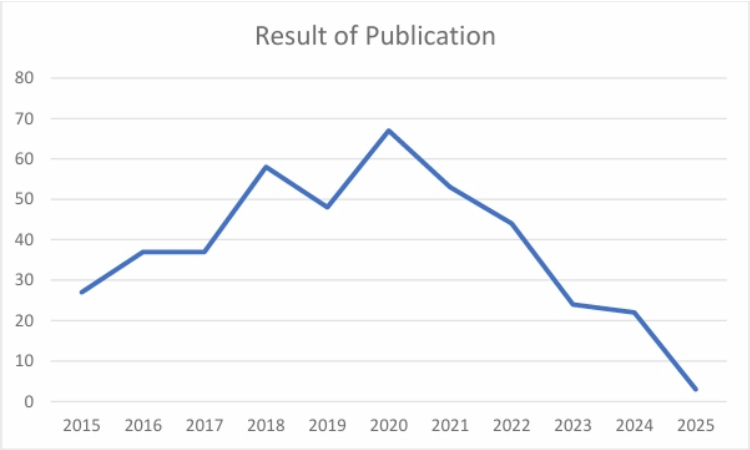

Figure 1. Annual Publication Results

2. Citation Trends in Spatial Thinking Research in Elementary School

Table 2 presents the ten most highly cited documents on spatial thinking in elementary school, included in this study as evidence that spatial thinking remains a relevant and prominent topic in elementary education. A selection of the most-cited published metadata is presented in Table 2.

Table 2. Spatial Thinking in Elementary School Articles with the Highest Number of Citations

No	Cites	Authors	Title	Year	Cites/Yr
1	509	N.M. Fuad, S. Zubaidah, S. Mahanal, E. Suarsini	*Improving Junior High Schools' Critical Thinking Skills Based on Test Three Different Models of Learning*	2017	63.63
2	401	J. Leonard, A. Buss, R. Gamboa, M. Mitchell, et al.	*Using robotics and game design to enhance children's self-efficacy, STEM attitudes, and computational thinking skills*	2016	44.56
3	400	S. Zubaidah, N.M. Fuad, S. Mahanal, et al.	*Improving creative thinking skills of students through differentiated science inquiry integrated with mind map*	2017	50.00
4	394	Y. Li, A.H. Schoenfeld, A.A. Disessa, A.C. Graesser, et al.	*Design and design thinking in STEM education*	2019	65.67
5	326	T. Lowrie, T. Logan, A. Ramful	*Visuospatial training improves elementary students' mathematics performance*	2017	40.75
6	305	I. Lee, S. Grover, F. Martin, S. Pillai, et al.	*Computational thinking from a disciplinary perspective: Integrating computational thinking in K-12 science, technology, engineering, and mathematics*	2020	61.00
7	279	A. Ramful, T. Lowrie, T. Logan	*Measurement of spatial ability: Construction and validation of the spatial reasoning instrument for middle school students*	2017	34.88

8	250	R. Lamb, T. Akmal, K. Petrie	*Development of a cognition-priming model describing learning in a STEM classroom*	2015	25.00
9	244	S. York, R. Lavi, Y.J. Dori, M.K. Orgill	*Applications of systems thinking in STEM education*	2019	40.67
10	222	D.J. Ketelhut, K. Mills, E. Hestness, L. Cabrera, et al.	*Teacher change following a professional development experience in integrating computational thinking into elementary science*	2020	44.40

Table 2 shows that the most frequently cited article in the field of spatial thinking in elementary school is the one written by Fuad et al., titled "Improving Junior High Schools' Critical Thinking Skills Based on Test Three Different Models of Learning," which has been cited 509 times, with an average of 63.63 citations per year. This article discusses how to improve critical thinking in learning by incorporating spatial elements. The second most cited article belongs to Leonard et al., with a total of 401 citations, titled "Using robotics and game design to enhance children's self-efficacy, STEM attitudes, and computational thinking skills." Meanwhile, only one article addresses spatial thinking in elementary school in depth, titled "Visuospatial training improves elementary students' mathematics performance." This finding is consistent with evidence that spatial skills in young children are closely linked to, and predictive of, later mathematics achievement, underscoring the importance of nurturing spatial ability from the early years of schooling (Verdine et al., 2017).

3. Visualization of the Research Data Mapping on Computational and Mathematical Thinking

The data mapped using VOSviewer produced three types of visualization: network visualization, overlay visualization, and density visualization. The network visualization shows that the terms drawn from the abstracts and keywords considered relevant to the keywords used during data collection are divided into six clusters, comprising a total of 103 items. Each item has a total link strength and an occurrence count. Overall, the total link strength amounts to 5,976, and the total number of links is 2,436. A more detailed explanation of each cluster is provided below.

Cluster 1 (red): *26 items: activity, addition, analysis, area, case study, child, concept, education, educator, effect, elementary school teacher, game, geography, geospatial technology, GIS, knowledge, mathematical thinking, place, role, school, sense, spatial thinking, spatial thinking skill, teacher, teaching, and tool.*

Cluster 2 (green): *20 items: achievement, aspect, gender, improvement, mental rotation, middle school student, motivation, performance, primary school, relation, relationship,*

spatial ability, spatial orientation, spatial reasoning, spatial skill, spatial visualization, study, term, type, and year.

Cluster 3 (dark blue): *19 items: approach, creative thinking, creative thinking skill, creativity, geometry, grade, implementation, Indonesia, inquiry, problem, process, project, representation, shape, skill, space, STEM, student, and thinking.*

Cluster 4 (yellow): *18 items: augmented reality, computational thinking, critical thinking skill, effectiveness, elementary school, elementary school student, impact, influence, lack, learning, mathematics, medium, program, research, science, science learning, technology, and young child.*

Cluster 5 (purple): *16 items: ability, assessment, challenge, context, development, elementary school child, elementary student, goal, instrument, model, paper, present study, reasoning, time, understanding, and use.*

Cluster 6 (light blue): *4 items: application, article, geometric thinking, and level.*

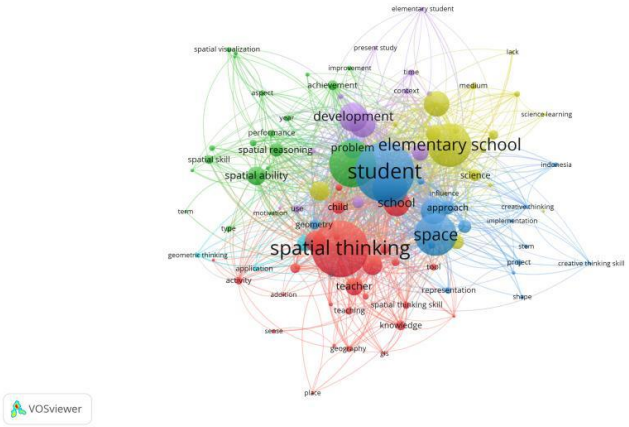

Figure 2. Network Visualization Based on Term Co-occurrence

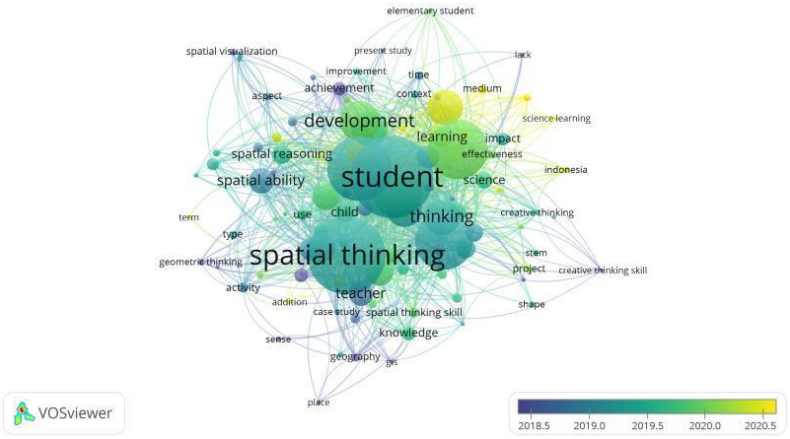

Figure 3. Overlay Visualization Based on Term Co-occurrence

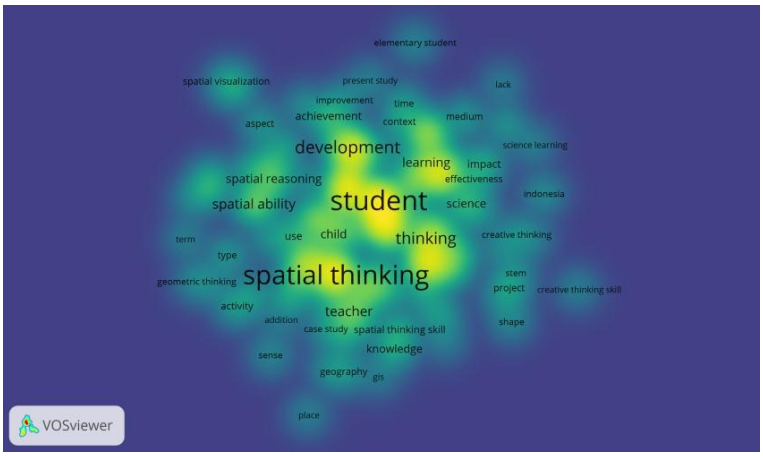

Figure 4. Density Visualization Based on Occurrence and Total Link Strength

Several keywords appear frequently and account for the greatest total link strength. First, the word student appears 125 times, with a total link strength of 649; second, spatial thinking appears 118 times, with a total link strength of 560; and third, elementary school appears 91 times, with a total link strength of 456.

CONCLUSION

This study aims to identify trends in the development of spatial thinking ability at the elementary education level through a bibliometric analysis approach. The method applied included data collection, identification, and visualization using the Publish or Perish and VOSviewer applications. The findings show that 420 articles were published between 2015 and 2025. Based on citation counts, the ten most-cited articles addressing spatial thinking in elementary school were identified. However, in-depth analysis reveals that only one of these ten articles specifically focused its discussion on spatial thinking at the elementary school level. This finding indicates a research gap and highlights the urgency of conducting further, more in-depth studies on spatial thinking within the context of elementary education.

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