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Spatial Literacy in Geometry Learning: A *Systematic Literature Review*

Dina Octaria[1], Zulkardi[2*], Ratu Ilma Indra Putri[3], Cecil Hiltrimartin[4]
Universitas Sriwijaya, Palembang, Indonesia[1,2,3,4]
dinaoktaria@gmail.com[1], zulkardi@unsri.ac.id[2], ratuilma@unsri.ac.id[3],
hiltrimartincecil@yahoo.com[4]

ABSTRACT

Spatial literacy, as a subset of mathematical literacy, integrates three core domains: visualization, reasoning, and communication. This systematic literature review aims to investigate the application of spatial literacy in geometry education, drawing on existing research findings, and to identify strategies that effectively enhance students' spatial skills within this context. Employing the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines ensures a systematic and structured approach to the review process. Data were sourced from platforms such as Google Scholar, Web of Science, and Scopus, encompassing publications from 2020 to 2024. The findings reveal that spatial literacy in geometry education is fostered through the use of visual aids, geometric models, activities emphasizing mental rotation and transformation, and the integration of spatial language. Additionally, strategies to improve students' spatial literacy include leveraging technology, implementing project-based learning, fostering collaborative group work, and engaging students in physical exploration.

Keywords : spatial literacy, geometry learning, systematic review

ABSTRAK

Literasi spasial merupakan bagian dari literasi matematika yang mencakup tiga domain utama yaitu visualisasi, penalaran, dan komunikasi. Tujuan dari tinjauan literatur sistematis ini adalah untuk mengkaji bagaimana konsep literasi spasial diterapkan dalam pembelajaran geometri berdasarkan hasil penelitian yang telah dilakukan, serta apa saja strategi pembelajaran yang efektif untuk meningkatkan literasi spasial siswa dalam konteks pembelajaran geometri. Metode yang digunakan mengikuti Standar *Preferred Reporting Items for Systematic Review* dan *Meta-Analysis* (PRISMA) untuk memastikan kajian ini dilakukan secara sistematis dan terstruktur. Sumber data yang dianalisis berasal dari database seperti *Google Scholar*, *Web of Science*, dan *Scopus* yang dipublikasikan antara tahun 2020 sampai 2024. Hasil tinjauan menunjukkan bahwa konsep literasi spasial dalam pembelajaran geometri diterapkan melalui penggunaan representasi visual dam model geometri, latihan rotasi dan transformasi mental, serta penggunaan bahasa spasial. Sementara itu, strategi pembelajaran yang efektif untuk meningkatkan literasi spasial siswa meliputi strategi berbasis teknologi, pembelajaran berbasis proyek, kolaborasi kelompok, serta eksplorasi fisik.

Kata kunci : Literasi spasial, pembelajaran geometri, tinjauan sistematis

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INTRODUCTION

Geometry, an essential branch of mathematics, plays a key role in developing logical thinking, laying the foundation for advanced mathematical knowledge (Octaria et al., 2024), and fostering spatial intuition relevant to real-world contexts. Through geometry, learners acquire reasoning and geometric modeling skills, enabling them to solve complex problems (Cesaria & Herman, 2019; Usiskin, 1982). By engaging with geometry, students can imagine, construct, and understand the structural properties of shapes while connecting them with related facts (Shadaan & Leong, 2013). These activities align closely with spatial literacy, which encompasses mental processes such as observing, manipulating, constructing, presenting, transforming, interpreting, and communicating two- and three-dimensional objects (De Lange, 2003; Güney, 2019; Lane et al., 2019).

In the current era of rapid technological and informational progress, mastering spatial literacy has become increasingly crucial. This ability extends beyond solving geometry, physics, chemistry, and geography problems to practical applications in daily life (De Lange, 2003; Setiani & Rafianti, 2018; Sutarna & Maryani, 2021). Spatial literacy, an essential skill for all individuals (Sari et al., 2022; Sorby & Panther, 2020), is defined as the ability to perceive and understand spatial objects (De Lange, 2003) and comprises three domains: visualization, reasoning, and communication (Ramful et al., 2017).

Visualization involves creating mental representations of spatial objects using visual images, external representations, or physical activities (Azzahra, 2022). This skill entails systematically manipulating an object’s form while preserving its core structure and relationships (Harris et al., 2023; Lowrie et al., 2020). According to (Patahuddin et al., 2018), visualization entails manipulating objects mentally by altering their positions or shapes through transformations or decompositions. This ability helps individuals predict the outcomes of spatial operations on objects, including rotating objects in 2D and 3D spaces, visualizing perspectives, folding 2D patterns into 3D shapes, interpreting orthogonal projections, and reorganizing shapes into components (Battista et al., 2018).

Spatial reasoning, encompassing skills like mental rotation and spatial orientation (Lowrie et al., 2021), refers to the ability to represent and analyze objects and their relationships in two or three dimensions (Pradana & Sholikhah, 2023; Sezen Yüksel, 2017). Clements and Battista describe it as a cognitive process involving the creation, manipulation, and transformation of mental representations of spatial objects and their interrelationships. Lohman adds that spatial reasoning entails creating, maintaining, and transforming visual images in a structured manner (Septia et al., 2018).

Communication, another critical domain of spatial literacy, focuses on conveying spatial ideas through language, writing, or gestures (Moore-Russo et al., 2013). It involves combining cognitive and social processes, such as describing or drawing spatial objects, to facilitate understanding (Gauvain & Rogoff, 1989). Educators must not only teach visualization and reasoning but also nurture the ability to communicate and comprehend spatial concepts expressed by others. Research by (Mas’udah et al., 2021) highlights that while students excel in visualization and reasoning, their communication skills for articulating spatial concepts remain underdeveloped.

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Students proficient in spatial literacy can visualize spatial objects, analyze their properties and relationships, and effectively communicate spatial information (Mas'udah et al., 2021). This study aims to address two key research questions: (1) How is spatial literacy applied in geometry education based on current research? (2) What strategies are most effective for enhancing students' spatial literacy in the context of geometry learning?

METHOD

A systematic literature review was undertaken to comprehensively analyze the body of literature on spatial literacy in geometry education, following the framework established by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). According to Sierra-Correa et al. (Subramaniam et al., 2022), PRISMA provides significant advantages, including the formulation of precise research questions to support systematic inquiry, the development of robust inclusion and exclusion criteria, and the facilitation of structured analyses of publications retrieved from extensive scientific databases within a specified timeframe. The review was conducted through four methodical stages: identification, screening, eligibility assessment, and inclusion (Page et al., 2021).

The identification phase commenced with defining the study's background, research questions, and objectives, followed by data collection using the keyword "spatial literacy." Literature searches were conducted across databases such as Google Scholar, Web of Science, and Scopus. Subsequently, the screening stage involved selecting articles based on inclusion and exclusion criteria specified in Table 1. This phase restricted the review to articles published between 2020 and 2024, with a minimum requirement of being indexed in accredited Sinta 3 journals. The scope was narrowed to content focusing on geometry, while the accepted types of literature included research articles, excluding books, book series and chapters, literature reviews, and conference proceedings.

Table 1. The eligibility and exclusion parameter

Parameter	Eligibility	Exclusion
Literature type	Journal (research-based)	Books, book series, chapters, systematic review articles, and conference proceedings
Language	English	Non-English
Timeline	Publications from 2020 to 2024	Publications before 2020

The next phase following the screening process was the eligibility stage, during which the authors conducted a detailed examination of the selected articles to verify their compliance with the established criteria. This involved a thorough review of the titles, abstracts, and full content of each article. The final phase, inclusion, focused on identifying concepts and effective teaching strategies aimed at enhancing students' spatial literacy in geometry education, as emphasized in the publications analyzed in this systematic review (see figure 1). A total of 16 articles were selected from the databases Google Scholar, Web of Science (WoS), and Scopus. These databases were chosen due to the high quality and distinctive characteristics of the publications they host.

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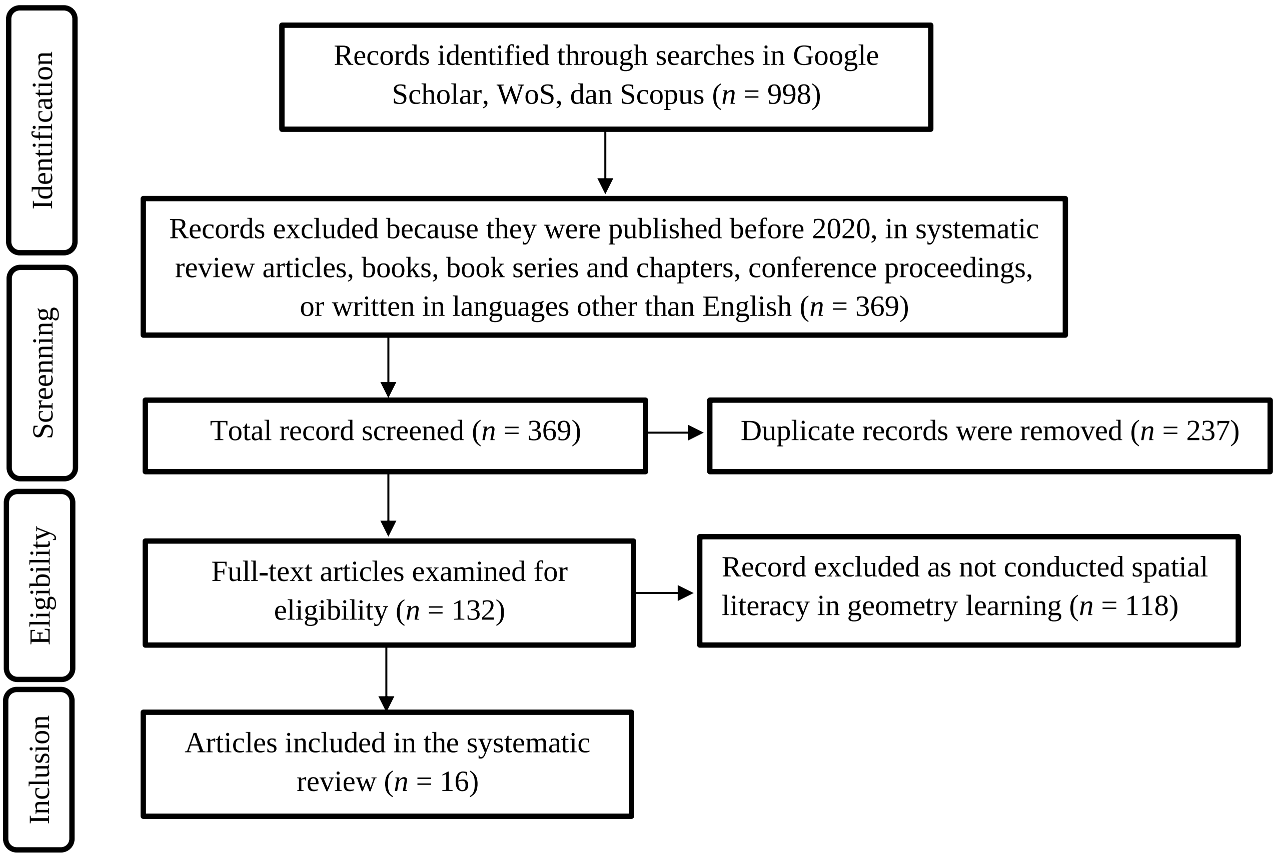

Figure 1. PRISMA systematic review

RESULTS AND DISCUSSION

Spatial Literacy in Geometry Learning Based on Publication Year

Publication trends serve as a key indicator in identifying the progress of a particular field. Between 2020 and 2024, several articles discussed spatial literacy in geometry learning. A total of 16 articles were selected in accordance with the research questions posed. Figure 2 presents the distribution of the articles by publication year.

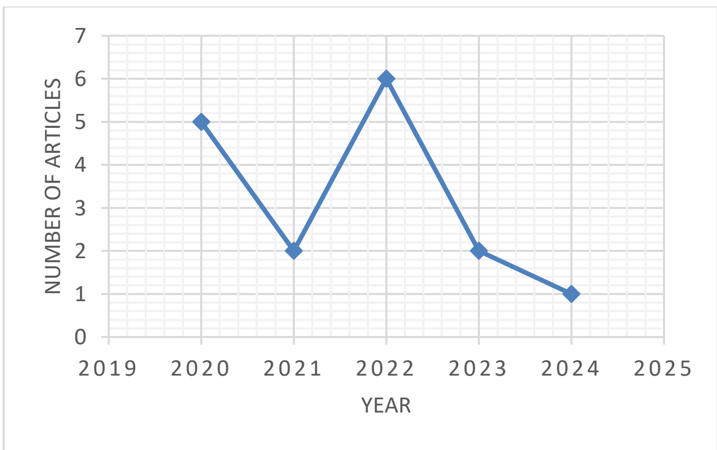

Figure 2. Distribution of articles on spatial literacy in geometry learning from 2020 to 2024

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The graph in Figure 2 illustrates a fluctuation in the number of articles on spatial literacy research in geometry education. Between 2020 and 2021, there was a noticeable decrease in the number of publications. However, this trend reversed, showing an increase from 2021 to 2022. Subsequently, the period from 2022 to 2024 exhibited a gradual decline in the volume of research on this topic.

Countries with the Most Research on Spatial Literacy in Geometry Learning

This review includes contributions from seven countries. The findings reveal that Indonesia has the highest number of studies on spatial literacy in geometry education, with a total of seven studies. Similarly, the United States contributed three studies, while China conducted two studies. In contrast, only one study on spatial literacy in geometry learning was conducted in each of the following countries: the United Kingdom, South Africa, Australia, and Japan.

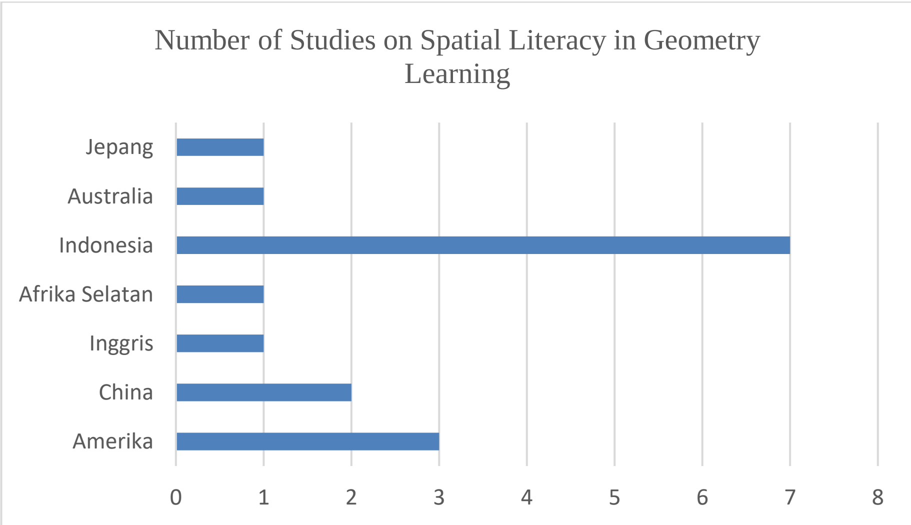

Figure 3. Number of studies on spatial literacy in geometry learning

Implementation of Spatial Literacy Concepts in Geometry Learning

Based on the analysis of various studies, the concept of spatial literacy in geometry learning is implemented through the following approaches:

1. **Using Visual Representations and Geometric Models**
   This encompasses the use of diagrams, graphs, and two-dimensional or three-dimensional geometric models. Students are guided to develop their ability to visualize geometric objects, comprehend spatial relationships, and mentally manipulate geometric shapes. Activities include visualizing complex objects, drawing them from multiple perspectives, and analyzing geometric structures. Numerous studies have demonstrated that visualization exercises significantly enhance spatial abilities, including geometric comprehension, spatial navigation, and problem-solving skills (Baranová & Katrenicová, 2018).
2. **Practicing Mental Rotation and Transformation**
   This pertains to the cognitive ability to mentally visualize an object in various orientations, including rotating or altering its position without any physical manipulation (Lin & Chen, 2016). Through these exercises, students are trained to mentally perform rotations, reflections, and transformations of geometric objects. Such practices play a crucial role in fostering spatial literacy, particularly in understanding concepts like symmetry and geometric transformations.

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3. **Using Spatial Language**
   Educators introduce terms such as "rotation," "orientation," "symmetry," and "transformation" to enhance students' understanding and ability to articulate spatial relationships effectively. Exposure to spatial relationships described through language aids students in encoding and retrieving essential spatial information (Bower et al., 2020; Gilligan-Lee et al., 2021).

Effective Teaching Strategies to Enhance Spatial Literacy in the Context of Geometry Learning

Based on an analysis of various studies, effective teaching strategies for enhancing students' spatial literacy in geometry learning include the following:

1. **Technology-Based Strategies**
   The integration of software, Augmented Reality (AR), Virtual Reality (VR), and other digital tools has proven to be an effective approach to improving students' spatial visualization skills (Shongwe, 2022). AR is a technological application that overlays 3D graphic data onto the real world. Key features of AR include the integration of real and virtual environments, real-time interaction, and the representation of objects as 3D models (Guntur et al., 2020). By utilizing AR, students can engage in activities that strengthen spatial skills such as mental manipulation, rotation, and reflection of objects. Furthermore, AR has been shown to enhance spatial visualization and mental rotation abilities (İbili et al., 2020).
2. **Project-Based Learning Strategies**
   Involving students in real-world projects provides practical opportunities to apply spatial reasoning and visualization skills, fostering the development of their spatial abilities (Priatna & Sari, 2022). These projects connect theoretical concepts with practical applications, creating meaningful learning experiences.
3. **Collaboration-Based Strategies**
   Group discussions and teamwork create environments where students can interact, share, and refine their spatial ideas. Collaborative discussions encourage students to explain, reason, argue, and defend their spatial reasoning, which promotes deeper understanding and critical thinking (Robertson & Graven, 2020).
4. **Physical Exploration Strategies**
   The use of physical manipulatives such as cube nets, tangrams, and 3D models supports the development of spatial literacy. Hands-on manipulation allows students to visualize and construct various shapes by mentally combining or rearranging components, a process integral to developing spatial imagination (Fujita et al., 2004; Kmetová & Nagyová Lehocká, 2021). These activities help bridge abstract concepts with tangible experiences, enhancing spatial reasoning skills.

CONCLUSION

This systematic review examined 16 articles on spatial literacy in geometry education. The analysis revealed an increase in the number of publications in 2021 and 2022, followed by a decline after 2022. Notable contributions to the field were made by researchers from Indonesia, the United States, and China. The review highlights that spatial literacy is developed through various methods, including visual representations, geometric models, mental rotation and transformation exercises, and the application of spatial language. To support this development, effective

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instructional strategies identified include integrating technology, implementing project-based activities, fostering collaboration, and utilizing hands-on exploration. This study recommends broadening the research focus by examining and comparing instructional methods and their effectiveness across diverse educational contexts. Particular attention could be given to countries with exceptional performance in mathematics education, such as Finland, Japan, and Singapore.

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