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Developing Spatial Thinking Competence and Sustainability Awareness through Geography Learning: A Systematic Literature Review

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Abstract

Spatial thinking and sustainability awareness are essential competencies in geography education, particularly in addressing global environmental challenges. However, the development of these competencies among students remains suboptimal and is strongly influenced by the learning approaches employed. This study aims to analyze 12 scientific articles related to the development of spatial thinking skills and sustainability through geography learning. This study adopts a Systematic Literature Review (SLR) method using the PRISMA approach to ensure a systematic, transparent, and reproducible selection process. Articles were selected based on topic relevance, publication year (2016–2026), and alignment with the research focus. The findings indicate that the most dominant and effective learning models in enhancing spatial thinking skills are Problem-Based Learning (PBL) and Project-Based Learning (PjBL), followed by the Earthcomm model, which emphasizes real-world environmental contexts. In addition, the integration of geospatial technologies such as Geographic Information Systems (GIS), Google Earth, and ArcGIS has been shown to significantly improve students' spatial analysis, representation, and reasoning abilities. These approaches not only enhance spatial thinking skills but also strengthen students' awareness of sustainability issues. Therefore, the combination of innovative learning models and geospatial technology integration represents an effective strategy for supporting the development of spatial thinking and sustainability competencies in geography education.

Keywords: Geography Education, Spatial Thinking, Sustainability Education, Systematic Literature Review, Geospatial Technology, PBL, PjBL

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INTRODUCTION | مقدمة

Spatial thinking is recognized as a fundamental competency in geography education because it enables students to understand spatial patterns, relationships, and processes within the geosphere. This competence supports learners in interpreting geographic phenomena and making informed decisions related to environmental and regional issues. Spatial thinking also plays a crucial role in developing higher-order thinking skills, particularly in analyzing spatial data and solving real-world problems. In the context of modern education, spatial thinking is not only a cognitive skill but also an essential component of geospatial literacy. However, the development of this competence depends heavily on the quality of instruction and learning strategies applied in the classroom. Many geography learning practices still emphasize memorization rather than conceptual understanding. As a result, students often struggle to apply spatial concepts in practical contexts. Several studies have shown that students' spatial thinking abilities are still in the moderate category and require improvement. One of the main causes is the continued use of conventional teaching methods that lack contextual relevance. Traditional approaches often limit student engagement and reduce opportunities for active exploration of spatial concepts. According to (Astawa, 2022), learning activities that are less interactive contribute to low spatial thinking performance among students. This condition highlights the need for more innovative and student-centered learning approaches. Without meaningful learning experiences, students may find it difficult to connect geographic concepts with real-world situations. Therefore, improving spatial thinking skills remains a critical challenge in geography education.

To address this issue, researchers have explored various learning models designed to enhance spatial thinking. Problem-Based Learning (PBL) has emerged as one of the most effective approaches in this context. Buana & Putra (2023) found that the implementation of PBL supported by WebGIS significantly improves students' spatial thinking skills. This model encourages students to actively engage in problem-solving activities and develop confidence in analyzing spatial phenomena. Similarly, Mayonita et al. (2026) demonstrated that students taught using PBL achieved significantly higher spatial thinking scores compared to those in conventional classes. The interactive nature of PBL allows students to explore real-world problems in a structured manner. As a result, students are better able to understand spatial relationships and apply their knowledge effectively.

In addition to PBL, other instructional approaches have also shown promising results in enhancing spatial learning. Contextual and demonstration-based methods can increase student engagement and improve learning outcomes. Astawa (2022) reported that the application of contextual demonstration methods significantly improved students' spatial thinking skills across learning cycles. These approaches emphasize real-life connections, making abstract spatial concepts easier to understand. Furthermore, adaptive learning models based on cognitive theories have been developed to address memory retention issues. Rojulan et al. (2026) introduced an adaptive learning model based on the Forgetting Curve, which effectively improved students' retention of spatial concepts. This model highlights the importance of structured repetition in maintaining long-term understanding. Consequently, diverse learning strategies are essential for optimizing spatial thinking development.

Technological integration has also become a key factor in improving spatial thinking skills in geography education. The use of Geographic Information Systems (GIS) allows students to analyze spatial data more effectively. (Ramadhani et al. (2025) found that GIS-based learning significantly improves students' spatial analysis abilities and learning motivation. This technology enables learners to visualize geographic information in a more interactive and meaningful way. In addition, Google Earth Engine (GEE) has been utilized in STEM-based learning to support spatial analysis. Haris et al. (2025) demonstrated that the integration of GEE significantly enhances students' spatial thinking performance with a large effect size. These findings indicate that technology plays a crucial role in modern geography education. Therefore, integrating geospatial tools is essential for developing students' spatial competencies.

The integration of technology, pedagogy, and content knowledge is further emphasized through the GeoTPACK framework. This framework highlights the importance of aligning teaching strategies with appropriate technological tools. Purwanto et al. (2025) explained that the use of 3D map visualization can improve the effectiveness of geography learning. Through this approach, teachers can create more engaging and interactive learning environments. The GeoTPACK framework also supports the development of innovative teaching practices. By combining technological and pedagogical competencies, educators can better facilitate spatial understanding. This integration helps students to visualize complex spatial relationships more clearly. As a result, learning becomes more meaningful and impactful

Beyond cognitive development, geography education also plays a significant role in promoting sustainability awareness. Sustainability has become a global priority, particularly in relation to the Sustainable Development Goals (SDGs). Mazwan et al. (2025); Lase et al. (2025) emphasized that geography education contributes to environmental literacy and spatial awareness. Students with strong spatial thinking skills are better equipped to understand environmental challenges and propose sustainable solutions. Geography learning also supports the development of responsible attitudes toward natural resource management. Through spatial analysis, students can evaluate the impact of human activities on the environment. This makes geography education highly relevant in addressing sustainability issues. Therefore, integrating sustainability perspectives into spatial learning is essential.

Despite the growing number of studies, most research tends to focus on specific aspects of geography learning. Some studies emphasize learning models, while others focus on technological integration. However, there is still a lack of comprehensive research that combines spatial thinking development with sustainability perspectives. This indicates a significant gap in the literature that needs to be addressed. A systematic approach is necessary to synthesize findings from various studies. Such an approach can provide a more holistic understanding of effective geography learning strategies. By integrating multiple perspectives, researchers can identify broader patterns and implications. Therefore, further research is required to bridge this gap.

Based on these considerations, this study aims to conduct a systematic literature review to analyze the development of spatial thinking and sustainability in geography education. The objectives of this study are threefold. First, it seeks to identify effective learning models that enhance spatial thinking skills. Second, it examines the role of geospatial technologies in supporting geography learning. Third, it analyzes the impact of these approaches on students' sustainability awareness. Through this study, a comprehensive understanding of geography education practices can be achieved. The findings are expected to contribute to the improvement of teaching strategies and curriculum development. Ultimately, this study aims to support the integration of spatial thinking and sustainability in education.

METHOD | منهج

This study employed a Systematic Literature Review (SLR) method guided by the PRISMA framework to ensure that the processes of identification, selection, and reporting of literature were conducted systematically, transparently, and reproducibly. The data source for this study was a single academic database, namely Google Scholar. This database was selected due to its broad coverage and its ability to index a wide range of scientific publications, including both national and international journals. The literature search was conducted using the following Boolean search string:

("spatial thinking" OR "spatial ability") AND ("geography education" OR "geographic learning") AND ("learning model" OR "instructional model") AND ("geospatial technology" OR GIS OR "remote sensing") AND ("sustainability education" OR "education for sustainable development")

The initial search yielded 114 articles. To ensure the relevance and recency of the studies, a publication year limitation was applied, including only articles published between 2016 and

2026. The screening process was then carried out by removing duplicate records and excluding irrelevant articles based on titles and abstracts. After the initial screening stage, 31 articles were selected for eligibility assessment through full-text review. At this stage, articles that were not available in full text or did not align with the research focus were excluded. The final selection resulted in 12 studies that met all inclusion criteria and were included in the systematic analysis. This number has been consistently used throughout the study.

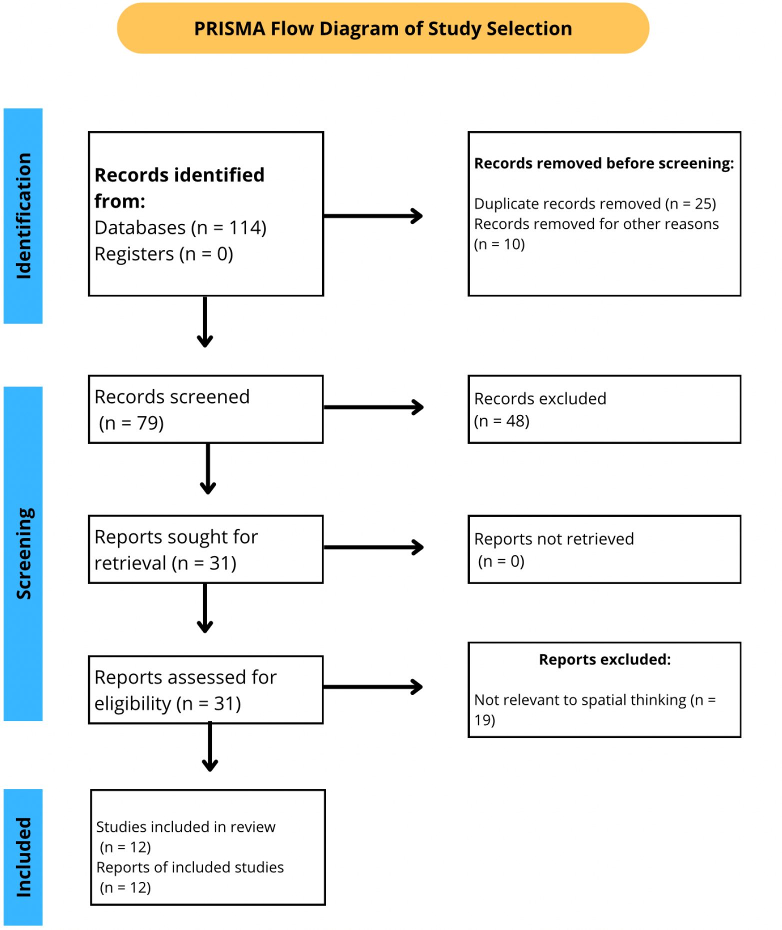

Figure 1. PRISMA Flow Diagram of Study Selection

The inclusion criteria were as follows:

(1) studies addressing spatial thinking within the context of geography education,
(2) articles discussing learning models or instructional strategies,
(3) studies involving geospatial technologies, and
(4) peer-reviewed journal publications.

The exclusion criteria included non-academic articles, conceptually irrelevant studies, and publications without full-text access. To ensure methodological quality, each selected study was evaluated using a quality assessment instrument adapted from the Joanna Briggs Institute. The assessment was based on several indicators, including clarity of research objectives, appropriateness of research design, validity of data collection methods, rigor of data analysis, and consistency between results and conclusions. Only studies with at least moderate quality were retained for the final analysis. Data analysis was conducted using thematic synthesis to identify patterns, key themes, and relationships among findings across the selected studies.

RESULT | نتائج

The following table presents a synthesis of selected studies examining the development of spatial thinking skills in geography education, with particular attention to learning models, technological integration, and sustainability perspectives. The studies included in this review represent various research designs, including experimental, qualitative, mixed-method, and literature review approaches. Each study contributes to understanding how spatial thinking can be improved through different instructional strategies and tools. In addition, the table highlights key findings related to the effectiveness of learning models such as Project-Based Learning (PjBL), Problem-Based Learning (PBL), and Earthcomm, as well as the role of geospatial technologies. By organizing the findings into comparable components, this table enables a clearer identification of patterns, similarities, and differences across studies. Furthermore, it provides a foundation for deeper analysis regarding the integration of spatial thinking and sustainability in geography learning. This synthesis is essential to support the formulation of more comprehensive and contextually relevant educational strategies.

Table 1. Summary of Previous Studies on Learning Models, Technology Integration, and Their Impact on Spatial Thinking and Sustainability in Geography Education

No.	Author	Design	Sample	Result	Comparing Conclusion
1	(Aulya et al., 2025)	Literature study (25 articles, 2014–2024)	Previous studies synthesis	Project-Based Learning (PjBL) significantly improves spatial thinking through contextual and active learning	Compared to other approaches, PjBL is effective in enhancing spatial thinking when supported by contextual tasks
2	(Bearman et al., 2016)	Conceptual analysis / education review	GIS education practices	GIS teaching often focuses on technical skills but lacks critical spatial thinking development	Compared to technical GIS teaching, integrating problem context is more effective for critical spatial thinking
3	(Jo, 2018)	Literature review	Previous studies synthesis	Spatial thinking is increasingly integrated in geography curriculum, instruction, and assessment	Compared to earlier studies, integration of spatial thinking in curriculum remains inconsistent
4	(Jo & Hong, 2018)	Literature review (special issue introduction)	Previous studies synthesis	The development of geospatial thinking enhances students' knowledge, skills, and spatial practices through curriculum, pedagogy, and geospatial technologies	Compared to traditional geography learning, geospatial technology-based approaches are more effective in developing spatial literacy and preparing students as 21st-century citizens
5	(Nursa'ban & Mukminan, 2023)	Evaluation research (DEM model)	208 students, 5 teachers	Spatial representation-based learning improves spatial critical thinking more than textbook learning	Compared to conventional learning, spatial representation is more effective in developing spatial reasoning
6	(Ridha et al., 2020)	Quasi-experimental	68 students	ArcGIS Story Maps improve spatial visualization, orientation, and mental rotation	Compared to non-digital learning, GIS-based tools enhance spatial thinking more interactively
7	(Nugroho et al., 2025)	Mixed method (explanatory sequential)	72 students	Students' spatial thinking mostly at moderate level; limited media is a barrier	Compared to intervention studies, lack of technology reduces spatial thinking performance
8	(Enshanty & Kurniawan, 2025)	Qualitative case study	High school students	Contextual PjBL improves spatial thinking and disaster literacy	Compared to traditional methods, contextual learning strengthens spatial and environmental awareness
9	(Zalfa et al., 2023)	Literature study	Previous studies synthesis	Spatial literacy requires integration of learning models and media	Compared to single-method learning, combined model + media is more effective
10	(Silviariza et al., 2021)	Experimental research	78 Geography students	The SPBL (Spatial-Problem Based Learning) model improves students' critical thinking skills, with 25% reaching a very critical level,	Compared to traditional learning, SPBL is more effective in enhancing students' critical thinking and spatial problem analysis, but its implementation

				although overall effectiveness is still below 40%	still needs optimization to achieve higher effectiveness
11	(Musafiri & Lestari, 2025)	Literature review	Previous studies synthesis	STEM integration strengthens spatial analysis and critical thinking	Compared to conventional geography learning, STEM provides broader competencies
12	(Azzahra et al., 2023)	Development research (4D model)	High school students	GIS-based multimedia improves spatial thinking ability significantly	Compared to conventional learning, GIS-based multimedia is more effective in improving spatial skills

DISCUSSION | مناقشة

Based on the comparison of the studies presented above, it can be observed that the development of spatial thinking skills is strongly influenced by the use of innovative and student-centered learning models. Project-Based Learning and Problem-Based Learning consistently demonstrate significant effectiveness in enhancing various aspects of spatial thinking, particularly when combined with real-world contexts. In addition, the integration of geospatial technologies such as GIS and ArcGIS contributes to improving students' analytical and visualization abilities. Several studies also emphasize the importance of contextual and sustainability-oriented learning, which not only strengthens spatial understanding but also fosters environmental awareness. However, some findings indicate that the effectiveness of these approaches depends on factors such as implementation time, teacher readiness, and availability of learning resources. Compared to conventional methods, interactive and technology-supported learning shows more meaningful learning outcomes. Therefore, a combination of appropriate learning models, technological tools, and sustainability integration is necessary to optimize spatial thinking development. These findings reinforce the need for a more holistic approach in geography education that aligns with current global challenges.

Learning Models in Developing Spatial Thinking

Project-Based Learning (PjBL) consistently emerges as the most influential instructional model in enhancing spatial thinking competence in geography education. (Aulya et al., 2025) confirm that PjBL significantly improves spatial thinking through structured inquiry, contextual learning, and authentic problem-solving activities. This model positions students as active knowledge constructors rather than passive recipients of information, which is essential in developing spatial reasoning skills. Through engagement in real-world geographic issues, students are trained to analyze spatial relationships, interpret data, and formulate evidence-based solutions. (Enshanty & Kurniawan, 2025) further emphasize that PjBL not only improves cognitive spatial skills but also strengthens disaster literacy and environmental awareness. This dual impact indicates that PjBL contributes to both academic achievement and sustainability-oriented competencies. Therefore, PjBL represents a pedagogically strong model that bridges spatial cognition and real-world environmental responsibility.

However, the effectiveness of PjBL is highly dependent on the quality of its implementation, particularly in terms of task design and contextual relevance. When projects are poorly structured or disconnected from real spatial problems, the learning impact tends to be superficial. Students may become engaged in activities without truly developing deep spatial reasoning skills. This suggests that PjBL is not inherently effective unless supported by strong pedagogical planning and teacher facilitation. Compared to conventional instruction, PjBL offers more meaningful learning experiences, but it also demands higher instructional competence from educators. In many contexts, teachers still struggle to design spatially meaningful projects due to limited training or resources. Therefore, the success of PjBL should be understood as conditional rather than absolute.

In addition to PjBL, Problem-Based Learning (PBL) plays a critical role in developing spatial thinking by emphasizing analytical reasoning and structured problem-solving. PBL requires students to identify geographic problems, collect spatial data, and evaluate possible solutions based on evidence. This process strengthens higher-order thinking skills, particularly spatial analysis and decision-making abilities. Unlike traditional lecture-based instruction, PBL places students in active cognitive roles where they must construct understanding through inquiry. The nature of geographic problems, which are inherently spatial and contextual, makes PBL highly suitable for geography education. However, the effectiveness of PBL also depends on the complexity and authenticity of the problems presented. If problems are too simplistic, the development of spatial thinking may remain limited and procedural rather than analytical.

Spatial representation-based learning further strengthens spatial cognition by emphasizing visual and symbolic interpretation of geographic information. (Nursa'ban & Mukminan, 2023) found that this approach significantly outperforms textbook-centered learning in developing spatial critical thinking. The use of maps, diagrams, and spatial models allows students to internalize abstract geographic concepts more effectively. This visual learning process supports mental mapping, spatial orientation, and relational thinking. Compared to rote memorization approaches, spatial representation promotes deeper cognitive engagement and conceptual understanding. It also helps students connect theoretical knowledge with spatial realities in a more structured way. Nevertheless, the effectiveness of this approach is often constrained by the availability and quality of spatial learning media in classrooms (Silviariza et al., 2021).

Despite the positive contributions of these learning models Jo (2018) highlights a persistent gap between curriculum design and classroom implementation of spatial thinking. Although spatial thinking is increasingly acknowledged in educational policies, its practical application remains inconsistent across schools. This inconsistency is influenced by uneven teacher readiness, limited instructional resources, and lack of systematic training. As a result, spatial thinking is often reduced to theoretical discussion rather than embedded cognitive practice. Zalfa et al. (2023) further argue that spatial literacy cannot develop optimally without integrating learning models with appropriate instructional media. The separation between pedagogy and media weakens the effectiveness of spatial learning interventions. Therefore, a more integrated, systematic, and technology-supported instructional framework is urgently needed.

Overall, the analysis indicates that learning models play a decisive role in shaping spatial thinking development, but their effectiveness is not automatic. PjBL, PBL, and spatial representation approaches all demonstrate strong potential when implemented with appropriate pedagogical design and contextual relevance. However, their impact is highly dependent on teacher competence, learning environment, and availability of supporting resources. Without these conditions, even well-designed models may fail to produce meaningful spatial learning outcomes. This suggests that improving spatial thinking requires not only selecting the right learning model but also strengthening the entire instructional ecosystem. Therefore, future geography education must move beyond model adoption toward systemic instructional improvement. This is essential to ensure that spatial thinking development becomes both sustainable and consistently effective across educational contexts.

The Role of Geospatial Technology in Spatial Learning

Geospatial technology has become one of the most transformative components in contemporary geography education, fundamentally reshaping how spatial thinking is developed and practiced in the classroom. Its integration enables students to move beyond static representations of space toward dynamic, data-driven spatial analysis that reflects real-world complexity. demonstrate that ArcGIS Story Maps significantly enhance students' spatial visualization, orientation, and mental rotation abilities compared to conventional learning approaches. This finding is important because these cognitive components are foundational to spatial thinking, yet they are often weakly developed in traditional classroom settings. Through interactive mapping systems, learners can visualize spatial relationships in layered, non-linear formats that better reflect geographic reality. Azzahra et al. (2023); Yanto et al. (2025) further support this argument by showing that GIS-based multimedia learning significantly improves spatial thinking performance. The combination of visual, textual, and spatial data representation creates a more immersive learning experience that strengthens cognitive engagement. However, this apparent effectiveness should not be interpreted as an inherent property of the technology itself, but rather as a result of how it is pedagogically structured. Without thoughtful instructional design, even the most advanced geospatial tools risk becoming superficial visualization instruments rather than cognitive development tools. Therefore, while geospatial technology offers substantial potential, its educational value is fundamentally dependent on instructional context (Ayuningtyas & Irawan, 2024).

Despite its benefits, a critical issue emerges in the way geospatial technology is frequently implemented in geography education, particularly in relation to GIS instruction. Bearman et al. (2016) critically argue that GIS education often prioritizes technical proficiency over conceptual and analytical understanding of spatial problems. In many instructional settings, students are primarily trained to operate software functions such as layering, buffering, and spatial querying without being guided to critically interpret the spatial meaning behind the outputs. This creates a form of "procedural competence" that does not necessarily translate into spatial reasoning ability. As a result, students may appear technologically skilled but lack deeper understanding of geographic relationships and spatial causality. This misalignment reflects a broader pedagogical problem where technology is treated as an end rather than a means of learning. Bearman et al. (2016) therefore emphasize the necessity of embedding GIS within authentic spatial problem contexts to ensure meaningful learning. Without such contextualization, GIS risks becoming a technical training tool rather than a cognitive learning medium. This critique highlights a fundamental tension in geospatial education: the gap between technical literacy and spatial thinking development. Addressing this gap requires a shift from tool-centered instruction to problem-centered pedagogy (Bana et al., 2025)

The integration of geospatial technology with interdisciplinary learning frameworks, particularly STEM education, offers a more comprehensive approach to addressing this limitation. Musafiri & Lestari (2025) argue that STEM-based integration significantly enhances spatial analysis, critical thinking, and problem-solving skills in geography learning. This approach positions geospatial technology not as an isolated instructional tool, but as part of a broader cognitive ecosystem that connects spatial reasoning with scientific inquiry and technological application. Dewi et al. (2025) further confirm that STEM-based geography learning produces more holistic competencies compared to conventional instructional approaches, including analytical reasoning, spatial modeling, and data interpretation skills. This suggests that spatial thinking development is most effective when supported by interdisciplinary learning structures that reflect real-world complexity. However, the effectiveness of STEM integration is not guaranteed automatically, as it depends heavily on curriculum design and teacher capacity. In many cases, STEM approaches are implemented superficially, focusing on integration labels rather than genuine cognitive integration. This raises critical concerns about whether STEM-based geospatial learning is truly transformative or merely rebranded traditional instruction. Therefore, careful pedagogical alignment is required to ensure that interdisciplinary integration translates into meaningful spatial cognition development.

A critical synthesis of the literature suggests that the effectiveness of geospatial technology is fundamentally determined by pedagogical design rather than technological sophistication. Technology alone does not inherently produce improved learning outcomes; instead, its impact is mediated by how it is embedded within instructional processes. Interactive systems such as GIS, ArcGIS, and Story Maps must be integrated into inquiry-based and problem-based learning environments to stimulate active spatial reasoning. When used in isolation, these tools risk reducing learning to visual exploration without analytical depth. Conversely, when embedded within structured problem-solving tasks, they function as cognitive scaffolding that supports students in constructing spatial understanding. This distinction is crucial because it shifts the focus from "using technology" to "using technology for thinking." Geospatial tools should therefore be understood as mediating instruments that facilitate cognitive engagement rather than replace it. Hawa et al. (2021) The literature consistently indicates that students achieve higher levels of spatial thinking when they are required to analyze, interpret, and justify spatial decisions using geospatial data. However, this only occurs when teachers deliberately design learning activities that require critical engagement rather than passive interaction. Thus, the pedagogical role of the teacher becomes central in determining the success of geospatial learning integration (Indraswari & Widiyatmoko, 2021).

Overall, the role of geospatial technology in spatial learning is best understood as both highly promising and deeply conditional. On one hand, tools such as GIS, ArcGIS, and digital mapping platforms offer unprecedented opportunities for enhancing spatial visualization, analytical reasoning, and data interpretation skills. On the other hand, their effectiveness is constrained by persistent pedagogical challenges, including overemphasis on technical training, lack of contextual learning design, and insufficient integration with higher-order thinking objectives (Khoirunnisa et al., 2025). The reviewed studies collectively suggest that geospatial technology is most impactful when it functions as part of a broader pedagogical framework that prioritizes inquiry, problem-solving, and conceptual understanding. Without this integration, there is a risk that technology will reinforce surface-level learning rather than deepen spatial cognition (Maryati et al., 2025). Therefore, the central challenge in geography education is not merely adopting geospatial tools, but transforming instructional practices to ensure these tools are used meaningfully. This requires a shift from technology-centered teaching to thinking-centered learning environments. In conclusion, geospatial technology should be positioned not as the driver of learning outcomes, but as a carefully mediated instrument that supports the development of critical spatial thinking and interdisciplinary competence.

Spatial Thinking and Sustainability Integration

The integration of spatial thinking and sustainability education represents a critical and increasingly urgent direction in contemporary geography learning, particularly in the context of global environmental uncertainty and escalating ecological crises. Spatial thinking is no longer sufficient to be positioned merely as a cognitive-geographical skill; instead, it must be understood as a foundational competence that shapes how students interpret, evaluate, and respond to sustainability challenges. Enshanty & Kurniawan (2025) demonstrate that contextual geography learning significantly improves disaster literacy and environmental awareness, indicating that spatial cognition directly influences students' understanding of environmental risk and resilience (Nurjanah et al., 2025). This finding is important because it shifts the role of geography education from knowledge transmission to decision-making preparation in real-world environmental contexts. By engaging students with authentic geographic problems, such as flooding, land degradation, or spatial inequality, learning becomes more than conceptual it becomes ethically and socially meaningful. However, this transformation only occurs when spatial learning is deliberately designed to connect cognitive processes with sustainability issues, rather than treating them as separate domains. Therefore, spatial thinking should be positioned as a bridge between geographic understanding and responsible environmental action, not as an isolated academic skill.

A more critical examination reveals that spatial representation-based learning plays a dual role in both cognitive development and sustainability awareness formation. Nursa'ban & Mukminan (2023) found that spatial representation significantly enhances students' ability to critically evaluate real-world geographic problems, particularly those related to environmental change and land use dynamics. This suggests that visual and representational tools such as maps, diagrams, and spatial models are not merely supportive media but essential cognitive instruments for interpreting complex sustainability issues. Through spatial representation, students are able to move beyond descriptive understanding toward analytical evaluation of environmental systems (Rahmawati & Irawan, 2024). As a result, sustainability is not taught as an abstract moral concept but as an evidence-based spatial phenomenon that can be observed, measured, and analyzed. Furthermore, this approach fosters critical awareness of the consequences of human-environment interactions, thereby strengthening ethical reasoning in geographic learning. Zalfa et al. (2023) reinforce this argument by emphasizing that spatial literacy requires a systematic integration of learning models and instructional media. Without this integration, spatial understanding remains fragmented, superficial, and disconnected from environmental realities. This indicates that instructional design is not a supporting factor but a determining condition in sustainability-oriented spatial learning.

However, despite these theoretical strengths, empirical findings reveal significant limitations in current classroom practices. Nugroho et al. (2025) report that students' spatial thinking abilities remain at a moderate level, primarily due to insufficient instructional media and the lack of structured analytical tasks. This finding is critical because it highlights a persistent gap between curriculum expectations and classroom implementation. Many geography learning environments still rely heavily on traditional methods that emphasize memorization rather than spatial analysis or problem-solving. As a result, students are rarely challenged to engage deeply with sustainability-related spatial issues in a meaningful way. The absence of interactive learning tools and inquiry-based tasks further reduces students' motivation and cognitive engagement. Consequently, sustainability education risks becoming declarative rather than transformative, where students are aware of environmental issues but lack the analytical capacity to respond to them. This limitation underscores a systemic weakness in geography education design, particularly in integrating spatial thinking with real-world sustainability problem-solving.

The synthesis of these findings indicates that the effectiveness of spatial thinking and sustainability integration is highly dependent on pedagogical quality and instructional coherence. Innovative learning models such as Project-Based Learning, Problem-Based Learning, and spatial representation approaches provide strong theoretical foundations for linking spatial cognition with sustainability awareness. However, their effectiveness is not automatic and requires deliberate instructional alignment with geospatial technologies and contextual learning environments (Yalçın et al., 2025) Studies consistently show that GIS-based tools, multimedia platforms, and interactive mapping systems significantly enhance students' spatial visualization and analytical abilities (Rakuasa & Latue, 2024). Nevertheless, these technologies can only contribute meaningfully when embedded within structured learning tasks that require critical thinking and environmental analysis. Without such integration, technology risks becoming a visual aid rather than a cognitive development tool. Therefore, the real challenge lies not in adopting innovative tools but in designing learning ecosystems that meaningfully connect pedagogy, technology, and sustainability objectives.

The integration of spatial thinking and sustainability education must be understood as a systemic educational transformation rather than a simple curriculum enhancement (Jo & Hong, 2018). The reviewed studies consistently demonstrate that spatial cognition is strongly linked to environmental awareness, disaster literacy, and sustainable decision-making capabilities. However, this relationship is highly conditional and depends on factors such as teacher readiness, instructional design quality, and availability of learning resources. As highlighted by multiple studies, including (Nugroho et al., 2025), limitations in learning environments significantly constrain the development of advanced spatial competencies. Therefore, geography education must move beyond fragmented instructional practices toward a holistic framework that integrates cognitive, technological, and sustainability dimensions. This requires a shift from content-centered teaching to problem-centered and inquiry-driven learning systems. In conclusion, the convergence of spatial thinking and sustainability education offers a powerful framework for preparing students to address complex global environmental challenges, but its success ultimately depends on the depth of pedagogical transformation within the classroom (Ridha et al., 2020).

Overall, the synthesis of findings suggests that spatial thinking development in geography education is most effective when supported by student-centered learning models, geospatial technologies, and interdisciplinary integration. Project-Based Learning, Problem-Based Learning, and spatial representation approaches consistently demonstrate strong effectiveness in enhancing spatial reasoning skills. Meanwhile, GIS, ArcGIS, and multimedia-based tools significantly contribute to students' spatial visualization and analytical abilities (Rimba et al., 2025). However, the effectiveness of these approaches is influenced by several contextual factors, including teacher readiness, availability of learning resources, and instructional design quality. As highlighted by (Nugroho et al., 2025), limitations in learning media can hinder the development of spatial thinking skills. Therefore, a more integrated and systematic approach is required to optimize learning outcomes. In conclusion, the combination of innovative pedagogical models, geospatial technology, and sustainability-oriented learning provides a comprehensive framework for enhancing spatial thinking competence in geography education. This integration not only improves cognitive skills but also fosters environmental awareness and critical decision-making abilities among students.

CONCLUSSION | خاتمة

This systematic literature review indicates that the development of spatial thinking competencies in geography education is significantly influenced by the integration of innovative learning models, geospatial technologies, and a sustainability orientation. Learner-centered approaches such as Project-Based Learning (PjBL), Problem-Based Learning (PBL), and spatial representation-based learning have proven to be far more effective than conventional methods in enhancing spatial reasoning, analysis, and visualization. The integration of technologies such as GIS, ArcGIS, and digital mapping tools further strengthens learners' ability to interpret complex data and geographic relationships. However, its effectiveness still depends on the quality of pedagogical design, educator competence, and the availability of learning resources, necessitating a balance between pedagogy, content, and technology.

This study confirms that spatial thinking is not merely a cognitive ability, but also a crucial foundation for fostering students' sustainability awareness. The results of the literature review indicate that geography education that integrates environmental issues, disaster contexts, and real-world spatial problems can enhance both environmental literacy and responsible decision-making skills. Through spatial thinking, students are able to analyze human interactions with the environment, assess the impacts of development, and formulate solutions to various global challenges. However, current educational practices still reveal gaps in integrating spatial thinking with sustainability concepts, primarily due to limitations in learning materials and the dominance of conventional methods. Therefore, a holistic and systematic learning framework is needed, one that integrates innovative learning models, geospatial technology, and a sustainability perspective in a cohesive manner. In this way, geography education can evolve from mere conceptual understanding toward transformative learning that equips students with spatial competencies and environmental responsibility, in alignment with global sustainability demands and 21st-century skills.

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