

GEOSPATIAL DEEP LEARNING: A CONTEXTUAL-CONSTRUCTIVE APPROACH TO GEOGRAPHY LEARNING TO EMPOWER SPATIAL THINKING SKILLS STUDENTS

Singgih Prihadi*, Chatarina Muryani, Sugiyanto, Rita Noviani, Imasti Dhani Pratiwi
Department of Geography Education, Faculty of Teacher Training and Education, Sebelas Maret University, Surakarta, Indonesia

*E-mail: singgihprihadi@staff.uns.ac.id

ARTICLE INFO

Article History

Received : 31/07/2025
Revised : 24/09/2025
Accepted : 15/12/2025

Citation:

Prihadi, S., Muryani, C., Sugiyanto., Noviani, R., and Pratiwi, I.D. (2026). Geospatial Deep Learning: A Contextual-Constructive Approach to Geography Learning to Empower Spatial Thinking Skills Students. GeoEco. Vol. 12, No. 1.

ABSTRACT

Geography education in the digital native era requires students to develop critical, creative, and innovative thinking through a spatial approach. Learning geography is not just about learning theory, but about learning deeply by optimising technology and geospatial data. This study aims to analyse the concepts and characteristics of Geospatial Deep Learning in geography education and to analyse the potential of Geospatial Deep Learning in empowering spatial thinking skills. This study employs a qualitative descriptive approach, utilising 10 informants of geography teachers and vice principals of senior high schools in Surakarta City. The sampling technique used is purposive sampling, as informants were selected based on the researcher's considerations. Data collection techniques include in-depth interviews and observations of teaching practices. The researcher employs an interactive data analysis model. The validity of the data used was triangulated by source and method. The research findings indicate that Geospatial Deep Learning in the context of high school geography education in Surakarta has already utilised geospatial data to enhance students' spatial thinking skills, though not yet to its full potential. Teachers have endeavoured to help students use data from Google Earth to strengthen their analysis. The potential of Geospatial Deep Learning in geography learning is significant, particularly in developing spatial thinking skills. Teachers noticed an improvement in spatial representation, which is evident in students' ability to visualise and manipulate spatial data in a more interesting, interactive, and informative way.

Keywords: *contextual-constructive; geospatial deep learning; spatial thinking*

INTRODUCTION

Education in the digital transformation era and the 5.0 industrial revolution requires critical thinking, creativity, and innovation with a spatial approach, which are essential competencies that

students must possess and apply, especially in geography learning. One of the primary skills students must master in geography education is spatial thinking, which refers to students' ability



to understand, interpret, and analyse location-based information across various scales and contexts of activities (National Research Council, 2006). Based on the researcher's observations, it was found that geography education in schools often focuses on memorising concepts and rarely involves students in meaningful contextual approaches.

Geospatial Deep Learning emerges as an innovative learning approach by integrating artificial intelligence technology, geospatial data, and constructivist learning principles to create a more interactive, reflective, meaningful, and contextual geography learning experience for students. Artificial intelligence technology, geographic information system platforms, and learning applications are essential for digital native students (Charzyński et al., 2025). Computational thinking and spatial thinking skills enable students to effectively address various environmental issues and disasters (Maddatuang et al., 2025). Through the geospatial deep learning approach, students are not merely recipients of information or understand information; they become active learners who comprehensively build knowledge through spatial data analysis, problem-

solving, and the development of data-based geographical understanding. Students learning geography must be able to interpret current global issues (Krause et al., 2024). This Geospatial Deep Learning approach aligns with the challenges of 21st-century learning, which emphasises the importance of optimising data literacy, technological literacy, and higher-order thinking skills. 21st-century geography education requires students to think critically to navigate the world's highly complex and dynamic changes (Silviariza et al., 2020). This approach is expected to be a strategic breakthrough in geography education in developing competencies relevant to today's global challenges and the dynamic and complex future. In today's global challenges, geography education does not always have to occur in the classroom. Still, students can be encouraged to learn outside the school, a pedagogical technique relevant to current conditions (Rock, 2022).

Geography education in the modern era plays a strategic role in helping students develop spatial literacy and sustainable environmental awareness. Based on observations and document analysis, researchers concluded that the geography learning process implemented



in schools is still oriented toward mastering theoretical facts alone. This situation hinders the development of students' spatial thinking skills in geography education, which include the ability to understand spatial relationships between geographical phenomena, visualise spatial patterns, and critically analyse regional dynamics. Spatial-based critical thinking skills are essential for enhancing community resilience to disasters and emergency response efforts, given that Indonesia is one of the countries most prone to disasters (Tomaszewski et al., 2020). With the advancement of increasingly sophisticated technology, particularly in spatial data, there is a huge opportunity to transform how geography is taught today. One innovative and constructive approach that is beginning to gain attention is Geospatial Deep Learning, which integrates deep learning approaches with complex geospatial data. This approach enables the processing of large-scale and complex geographic data. It can give students a deeper learning experience through visualisation, prediction, and spatial classification of issues raised in engaging lessons. Spatial thinking is a crucial asset in geography education.

Therefore, prospective geography teachers must be trained in spatial thinking (von Reumont & Budke, 2021). From the perspective of modern education, applying geospatial deep learning approaches can be utilised to create geography learning that incorporates the principles of mindfulness, meaningfulness, and joyfulness, based on contextual and constructive methods. Integrating geospatial technology, pedagogy, and knowledge is crucial to learning geography (Purwanto et al., 2024). This requires support from learning media that align with contemporary developments. Contextual geography learning means that geography learning materials are directly linked to phenomena and realities in the students' environment, so students are familiar with and have experienced them. Constructive geography learning emphasises the active role of students in building spatial understanding through authentic learning experiences. Through this approach, it is hoped that students will be able to engage directly in digital mapping, satellite image analysis, spatial data interpretation, and simulations of geographical dynamics using technology. In modern geography



education, the geospatial deep learning approach can help teachers empower students, encourage them to explore the real world through a spatial perspective, and develop higher-order thinking skills, such as analysis, evaluation, and creation (Krause et al., 2022).

In general, high school students' spatial thinking abilities vary from low to medium to high, depending on the school, material, and research context. Most research results indicate that spatial thinking abilities fall into the medium category, especially in problem-solving and complex conceptualisation skills. Some schools in Surakarta show high results, particularly in representation and spatial visual skills. The curriculum, type of material, and gender influence this. In the development of geography learning, a geospatial deep learning approach is necessary so that teachers can incorporate spatial data into more authentic learning experiences. A deep learning-based geospatial approach enables students to work directly with spatial data, including satellite imagery, digital maps, sensor data, mobility data, and earth surface models. Through this technology, students can view real-world representations in 2D/3D, understand spatial patterns, relationships, and

transformations more deeply, and experience authentic spatial thinking processes rather than merely learning symbols or static maps. This approach enhances academic competence and equips students with skills relevant to facing environmental, social, and technological challenges in the future. This approach will later coexist with the use of gadgets as well, except that the difference is that students are only allowed to hold their phones at certain times; otherwise, they are kept by a staff member.

This research is a study that has not been widely conducted in the context of geography learning. The author attempted to locate literature sources on the deep learning geospatial approach; however, there were still few publications available, posing a challenge for the researcher to conduct research on the geospatial concept in everyday life as part of meaningful learning.

MATERIALS AND METHODS

This study uses a descriptive qualitative approach to describe the concept and characteristics of Geospatial Deep Learning in empowering students' spatial thinking skills. The researcher chose a



qualitative approach because it is projected to be capable of exploring the meaning, value, and dynamics of the geospatial deep learning approach that cannot be measured quantitatively, as well as providing space for teachers' and students' narratives to bring out ideas and opinions authentically (Creswell, 2015). Administratively, the research was conducted at public and private high schools in Surakarta City, involving geography teachers and students.

The number of informants in this study was 10, selected using purposive sampling based on their direct involvement in deep learning socialisation activities. The informants consisted of 4 geography teachers from public high schools, four geography teachers from private high schools, and two vice principals in charge of curriculum. The selection of sources is based on their experience and ability to receive deep learning socialisation. The sources have practically implemented deep learning in geography subjects. Based on this condition, the researcher believes that these sources are valid.

The data collection technique used was in-depth interviews to explore the understanding, motivation, and values

underlying the practice of the Geospatial Deep Learning concept. The researcher also conducted participatory observation during field visits, systematically recording the activities of teachers and students in the context of applying the geospatial deep learning approach to empower spatial thinking skills. Documentation techniques were also employed to strengthen the data, including photos of activities, daily notes, and archives related to implementing the Merdeka Curriculum using the geospatial deep learning approach. The interview and observation guidelines can be seen in **Tables 1** and **2**. The data obtained by the researchers was then analyzed using interactive analysis techniques, with the following stages: 1) data condensation, by compiling interview transcripts and field notes; 2) data categorization based on the central theme, namely contextual-constructive geospatial deep learning; 3) drawing conclusions and verification through the process of matching multiple data sources (triangulation) and developing a descriptive narrative (Miles, Matthew B, A. Michael Huberman, 2014). The interactive model data analysis flowchart is shown in **Figure 1**.



Table 1. In-Depth Interview Grid

No.	Aspects Explored	Indicators
1	Understanding Geospatial Deep Learning	a. Definition and understanding of GDL b. Spatial and contextual concepts in geography learning
2	Experience in applying Geospatial Deep Learning	a. Use of geospatial media/tools (maps, GIS, satellite imagery, etc.) b. Contextual-constructive geography learning process c. Strategies for developing spatial thinking skills
3	Perceptions of the effectiveness of the Geospatial Deep Learning approach	a. Revelation to the curriculum b. Impact on student learning motivation c. Effectiveness in improving spatial thinking skills
4	Support and obstacles in the implementation of Geospatial Deep Learning	a. Availability of infrastructure (tools, internet, digital maps, etc.) b. School support and training c. Technical and pedagogical challenges
5	Recommendations for development	a. Recommendations for development b. Training needs c. Curriculum strengthening d. Improvement of learning media

Table 2. Observation Grid

No.	Observed Aspects	Indicators	Sub-Indicators / Focus of Observation
1	Application of contextual learning	a. Use of the surrounding environment as a learning resource b. Linking material to local realities	a. Teachers link material to real local/spatial issues b. Students are encouraged to reflect on local contexts such as flooding, spatial planning, etc.
2	Constructive approach in the learning process	a. Active learning activities for students b. Students build knowledge through exploration and discussion	a. Students discuss and construct their own understanding b. Teachers act as facilitators rather than sole sources of knowledge
3	Use of geospatial media and tools	a. Use of maps, satellite imagery, GIS, Google Earth, drones, etc. b. Integration of technology into the learning process	a. Teachers/students use geospatial visualisation tools b. Learning is supported by spatial-based technology (digital or manual)
4	Learning activities that develop spatial thinking skills	a. Ability to identify locations, spatial relationships, patterns, and distributions b. Ability to develop spatial-based problem-solving	a. Students are asked to read maps, identify directions/distribution patterns b. Students develop geospatial analysis in projects or assignments
5	Participation and response of students	a. Enthusiasm, active involvement, and curiosity of students b. Collaboration in groups	a. Students actively ask questions and express their opinions b. Students work together in spatial project groups



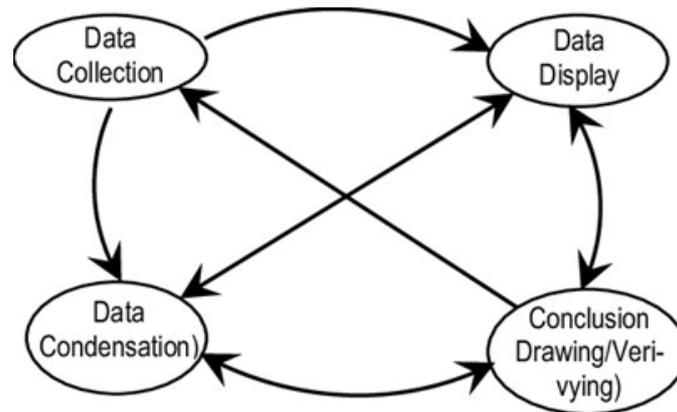


Figure 1. Data Analysis of the Interactive Model
Sources: (Miles Huberman & Saldana, 2014)

To obtain valid data, the researcher used source and method triangulation, which involves comparing information from various informants and data collection techniques. In addition, the researcher prepared a member check technique to confirm the initial interpretation results with the primary informants to ensure the accuracy and validity of the research results (Creswell, 2015).

RESULTS AND DISCUSSION

Spatial thinking skills are cognitive processes that enable us to understand the location, distribution, and spatial relationships between objects and phenomena on the Earth's surface. Spatial thinking encompasses three primary components: spatial concepts, tools of representation (such as maps, images, and models), and reasoning

processes. These skills are central to spatial-based geography learning (National Research Council, 2006). Constructivist geography learning encourages students to build knowledge through direct learning experiences and social interactions. In today's era, geography learning must be designed more innovatively so that students actively explore, analyse, and reflect on spatial data in real-world contexts.

Geospatial Deep Learning is an extension of deep learning applied to deep learning that utilises geospatial data, such as satellite imagery, vector data, and digital maps. In the future, it is hoped that geography education will optimise geospatial technology, enabling students to automatically extract patterns, classify regions, and predict geographical phenomena with high precision. This integration promotes



data-driven learning, which strengthens students' digital literacy and spatial skills in learning geography. These components form the conceptual basis for developing a contextual, constructive, high-tech approach to geography learning. The main objective is to effectively empower students' spatial thinking skills in facing the geospatial complexities of the 21st century (Wijayanto et al., 2023).

1. Concepts and Characteristics of Geospatial Deep Learning in Geography Education

Based on in-depth interviews and literature reviews, researchers concluded that Geospatial Deep Learning integrates deep learning technology with geospatial data, including satellite imagery, vector data, digital maps, and other spatial data. This technology can perform land classification, detect regional changes, and predict geographical phenomena automatically and in real time. In the practice of geography education in schools, the geospatial deep learning approach enables students to visualise spatial data through digital thematic maps and interactive satellite imagery. Simple artificial intelligence should be introduced in schools to help students

predict spatial patterns, such as urbanisation or land cover changes. Artificial intelligence in today's digital native era is often applied in the form of STEM. The STEM approach significantly impacts spatial thinking skills, geography skills, and students' attitudes toward geography learning (Putra et al., 2021). Teachers must be able to integrate geographic information with spatial modelling based on real-world problems. The main characteristics of the geospatial deep learning approach are that it is data-driven, exploratory, and provides space for students to build knowledge from direct interaction with digital spatial information.

The geospatial deep learning approach to geography education in high schools is a pedagogical approach that integrates artificial intelligence and geospatial technology. Teachers feel this approach can provide learning experiences based on real-world data and spatial phenomena. It is also important to note that artificial intelligence can be a cause for concern if its use is not adequately controlled, as it may increase students' reliance on shortcuts to pass exams quickly (Wilby & Esson, 2024). Teachers encourage students to develop



spatial problem-solving skills, critical thinking, and location-based decision-making. From a technical implementation and output perspective, this approach aligns with the independent curriculum that promotes project-based learning, contextual learning, and strengthening life skills and digital literacy. Spatial thinking skills are generally applied by students indirectly in various daily activities. For example, determining a route to a destination, predicting the spatial-temporal distribution of an event, and enhancing these abilities using geographic information systems (Duarte et al., 2022).

Geospatial Deep Learning in the context of geography learning in Senior High Schools in Surakarta, from the interview results, it was concluded that learning already uses geospatial data, although not yet optimally. Teachers facilitate students in using data from Google Earth to strengthen analysis. In more interesting learning practices, teachers have integrated artificial intelligence technology for visualisation and analysis based on problems given by teachers. The use of artificial intelligence technology is still minimal and needs to be improved. This aligns with a study

stating that artificial intelligence can convey spatial thinking skills to students. Even learning with hybrid learning technology can be used to train spatial thinking skills (Amin et al., 2020). The geospatial deep learning approach can encourage contextual and project-based learning. Contextual means studying subjects and objects that occur around students. For example, flood vulnerability can be analysed based on elevation data and land cover, which students generally already know and feel. Contextual learning projects based on projects that maximise the geospatial deep learning approach can include creating disaster risk maps or data-based spatial planning.

Geography learning assignments using a geospatial deep learning approach can build spatial thinking skills. Integrating a geospatial deep learning approach influences the interpretation of spatial patterns in connecting geographical variables. Student geography learning activities lead to the ability to analyse relationships between phenomena in space and time, by optimising digital literacy and collaboration. Digital literacy applied in high schools involves using digital platforms such as ArcGIS Online, QGIS, and Google Earth Engine



to strengthen students' digital competencies. This prepares students for college, where they will use spatial data in critical thinking processes (Bearman et al., 2016). In group learning, students are encouraged to collaborate in designing spatial solutions and presenting group analysis results. In this context, the principles of constructivism are effectively implemented. Through the geospatial deep learning approach, students actively build understanding

through spatial data exploration, experimentation, reflection, and discussion. Teachers should act as active facilitators, guiding the process, rather than being the sole source of information when applying the geospatial deep learning approach. An example of the implementation of the geospatial deep learning approach in high school geography education is shown in **Table 3**.

Table 3. Example of the Implementation of the Geospatial Deep Learning Approach in High School Geography Education

No.	Topic	Geospatial Deep Learning-Based Learning Activities
1	Population Dynamics	Students analyse population distribution and land use changes using aerial photographs, spatial data albums, and multi-temporal satellite imagery.
2	Regional Spatial Planning	Students practice social mapping and regional planning simulations based on spatial potential and constraints using digital mapping tools.
3	Climate Change	Students use spatial data in the form of satellite imagery to identify areas experiencing deforestation and their relationship to local temperatures.
4	Disaster Mitigation	Students create flood disaster mitigation maps by integrating rainfall data, slope gradients, elevation, and land cover information.

Source: Researcher Analysis, 2025

By integrating Geospatial Deep Learning into the Merdeka Curriculum in high school geography education, students understand geographical concepts theoretically and through memorisation and develop practical and critical skills to analyse real-world location-based problems. The real-world issues referred to here are environmental issues, highly relevant to geography education when

approached through problem-solving or project-based learning models (Wahelo et al., 2025). This makes geography education more relevant, active, and future-oriented (Lambert & Morgan, 2010).

2. The Potential of Geospatial Deep Learning in Empowering Spatial Thinking Skills



Based on observations of the learning process and in-depth interviews with teachers, it is known that the potential of Geospatial Deep Learning in geography learning is very significant, especially in developing spatial thinking skills. Teachers feel that there has been an improvement in spatial representation, as seen from the students' ability to visualise and manipulate spatial data in a more interesting, interactive, and informative way. These repeated student activities will strengthen spatial reasoning in identifying spatial patterns of the studied objects. This aligns with a research finding stating that geography education, cultivating spatial thinking skills, can be achieved through spatial representation design using infographics with visually appealing visualisations (Prihadi, 2023). From the interview results, the author concluded that students in geography learning are still weak in their ability to process spatial data using tools such as QGIS, Google Earth Engine, or other platforms that support artificial intelligence-based learning. By combining a constructive geospatial deep learning approach, students must actively use geospatial data and map literacy that guides them to think critically about location-based

information. This is in line with a study that states that map literacy can help achieve spatial thinking skills if all components and syntax are done correctly (Segara et al., 2018).

The contextual-constructive geospatial deep learning approach contributes significantly to the geography learning process. Based on theoretical analysis and in-depth interviews, it is evident that this approach effectively links geographical material contextually to real-world conditions students face, such as floods, traffic jams, droughts, landslides, or deforestation. This approach activates students as subjects of learning who construct their knowledge collaboratively and individually through mapping, observation, discussion, and group projects. These activities encourage students to think reflectively and at a higher level in solving location-based problems. Spatial thinking can develop optimally when students experience learning through direct experience and stimulate higher-level thinking skills and meaningful spatial data manipulation. In any context, the learning objectives of geography must be directed toward higher-order thinking skills (Virranmäki et al., 2021).



The contextual-constructive geospatial deep learning approach combines two main foundations: the Contextual Teaching and Learning (CTL) theory and the constructivist learning theory. In the Contextual Teaching and Learning (CTL) theory, learning materials are linked to students' real-life experiences, enabling knowledge to be built through direct experiences, observations of the environment or surroundings, problem-solving, and collaborative work in discussion groups. The learning process should be a series of basic and deep learning (Mthethwa-Kunene et al., 2021). Constructive learning carried out by students is a process of building knowledge together between teachers and students through experience, reflection, and social interaction. Constructive learning will make it easier for students to create knowledge. One way to help students easily build knowledge is through mind maps. The mind map technique produces visualisations that help students achieve meaningful learning. This is an essential component of geospatial deep learning (Ningrum et al., 2021). According to the informants, it can be concluded that constructive learning is successful when students actively construct their

understanding and that of their group, utilising all the available resources. From the two learning theories applied to geography learning, a geospatial deep learning approach was developed, which, in its implementation, focuses not only on content mastery but also on meaningful understanding, higher-order thinking skills, and the transfer of knowledge to new situations.

By integrating contextual-constructive deep learning into geography education, teachers can manage meaningful learning experiences. Students' spatial thinking skills will develop with active engagement in activities involving understanding, analysing, and interpreting location-based geographical phenomena. This is essential in preparing a spatially aware generation with technological literacy skills and responsive to environmental issues and sustainable development. In today's digital age, it is not enough to simply master technology; spatial thinking skills must also be strengthened. Spatial thinking is a fundamental competency that students must master in geography education, enabling them to understand the relationships between phenomena, locations, and patterns in space related to a particular issue. Students must master



spatial thinking because many problems are now analysed spatially, such as floods, housing density, and traffic flow. Important decisions made based on location analysis must also be taught to students so that they can understand and address contextual issues such as spatial planning, disaster mitigation, regional planning, and other societal problems.

The implementation of a geospatial deep learning approach in the classroom faces several obstacles, ranging from limitations in technological infrastructure, such as inadequate computers and internet networks for processing extensive spatial data, to low teacher competence in operating GIS, programming, and machine learning models. In addition, the complexity of geospatial data, which often requires preprocessing stages, can easily overwhelm students. Conversely, curricula that do not explicitly incorporate geospatial-AI integration often result in less directed classroom implementation. Other challenges include limited learning time for in-depth analysis activities, gaps in digital literacy among students, and minimal support from the school ecosystem, such as cross-subject collaboration and provision of technical assistance. All

these factors mean that the adoption of geospatial deep learning in the classroom still requires well-prepared pedagogical, technical, and institutional readiness.

CONCLUSIONS

Based on interviews and observations at high schools in Surakarta, it was found that implementing a deep geospatial learning approach has significant implications that substantially impact the education system. This approach has influenced teacher professional development and student competence because it has been integrated into independent curriculum learning.

The role of teachers has changed from being the primary source of information to being facilitators, technology mentors, and designers of spatial data-based learning. Teachers must be able to transform themselves if they want to create geography lessons that are successful and acceptable to students. The geospatial deep learning approach will minimise the number of teachers stuck in lecture-based and rote-learning methods. Teachers are conditioned to adopt a constructivist, exploratory, and project-based approach. As a result, teachers will become adaptive to



flexible, responsive, and integrated learning that incorporates spatial data. The application of the geospatial deep learning approach also has a significant impact on students. Students experience dynamic competency development that enables them to address 21st-century learning challenges through the mastery of critical thinking, problem-solving, data literacy, spatial reasoning, and digital fluency skills. From the perspective of gaining a meaningful understanding of environmental awareness, students become aware of environmental issues such as ecological degradation, disasters, and climate change by applying the geospatial deep learning approach. From a curriculum perspective, with the integration of the geospatial deep learning approach into the independent curriculum, it is necessary to revise the learning outcomes for high school geography to include spatial data interpretation skills and the use of artificial intelligence technology. To measure students' spatial and higher-order thinking abilities, authentic assessment should also be considered, particularly in project-based evaluations. Spatial thinking skills in today's modern era require the digitisation of schools. Hence, the

government must consider the need for software and geospatial data to support school geography learning. Of course, this will be easy if a strategic partnership exists between the government and geospatial institutions, universities, and the education-based business world. Implementing the Geospatial Deep Learning approach in high school geography education is crucial in preparing students as the next generation who are proficient in technology, sensitive to spatial issues, and capable of making strategic decisions based on spatial data. With the support of a healthy and equitable educational ecosystem, the geospatial deep learning approach within the independent curriculum will serve as a learning tool and a transformative effort to build spatial literacy and environmental awareness among high school students in Indonesia.

The limitation of research on this deep learning geospatial approach is that data collection is still limited to 8 schools in Surakarta City, so it cannot yet be generalised comprehensively. As a recommendation for future researchers, data collection should be conducted in all schools in Surakarta City to provide meaningful insights for students.



ACKNOWLEDGMENTS

We thank the Rector of Sebelas Maret University Surakarta for funding and granting permission for the research group's research, enabling the researchers to compile this article.

REFERENCES

- Amin, S., Sumarmi, Bachri, S., Susilo, S., & Bashith, A. (2020). The Effect of Problem-Based Hybrid Learning (PBHL) Models on Spatial Thinking Ability and Geography Learning Outcomes. *International Journal of Emerging Technologies in Learning*, 15(19), 83–94. <https://doi.org/10.3991/ijet.v15i19.15729>
- Bearman, N., Jones, N., André, I., Cachinho, H. A., & DeMers, M. (2016). The future role of GIS education in creating critical spatial thinkers. *Journal of Geography in Higher Education*, 40(3), 394–408. <https://doi.org/10.1080/03098265.2016.1144729>
- Charzyński, P., Świtoniak, M., & Urbańska, M. (2025). Geography from screens to streets—Navigating digital natives into real world. *Eurasia Journal of Mathematics, Science and Technology Education*, 21(3). <https://doi.org/10.29333/ejmste/15986>
- Creswell, J. (2015). *Educational Research Planning, Conducting, and Evaluating Quantitative and Qualitative Research*. Pearson.
- Duarte, L., Teodoro, A. C., & Gonçalves, H. (2022). Evaluation of Spatial Thinking Ability Based on Exposure to Geographical Information Systems (GIS) Concepts in the Context of Higher Education. *ISPRS International Journal of Geo-Information*, 11(8). <https://doi.org/10.3390/ijgi11080417>
- Krause, U., Béneker, T., & van Tartwijk, J. (2022). Geography textbook tasks fostering thinking skills for the acquisition of powerful knowledge. *International Research in Geographical and Environmental Education*, 31(1), 69–83. <https://doi.org/10.1080/10382046.2021.1885248>
- Krause, U., Béneker, T., van Tartwijk, J., & Güngör, D. (2024). Influences on the task-setting practices of geography teachers: orientations and curriculum contexts. *International Research in Geographical and Environmental Education*, 0(0), 1–15. <https://doi.org/10.1080/10382046.2024.2363642>
- Lambert, D., & Morgan, J. (2010). *Teaching Geography 11–18 A Conceptual Approach*. Open University Press. www.openup.co.uk
- Maddatuang, Bahri, A., & Tabbu, M. A. S. (2025). the Impact of Digital Literacy and Disaster Mitigation Understanding on Computational and Spatial Thinking Ability in Upper Secondary School Students. *Journal of Baltic Science Education*, 24(2), 312–325. <https://doi.org/10.33225/jbse/25.24.312>
- Miles, Matthew B, A. Michael Huberman, J. S. (2014). *Qualitative Data Analysis_ A Methods Sourcebook*. SAGE Publication, Inc.



- Mthethwa-Kunene, K., Rugube, T., & Maphosa, C. (2021). Rethinking Pedagogy: Interrogating Ways of Promoting Deeper Learning in Higher Education. *European Journal of Interactive Multimedia and Education*, 3(1), e02204. <https://doi.org/10.30935/ejimed/11439>
- National Research Council. (2006). *Learning to Think Spatially*. The National Academies Press.
- Ningrum, E., Yani, A., & Nandi. (2021). Meaningful Learning and Use of Mind-Map in Geography Subject at Senior High School. *Journal of Southwest Jiaotong University*, 56(1). <https://doi.org/10.35741/issn.0258-2724.56.1.21>
- Prihadi, S. (2023). The Effectiveness of SIHyL (Spatial Inquiry Hybrid Learning) Model in Improving Students' Spatial Citizenship in Geographic Learning. *International Journal of Information and Education Technology*, 13(4), 634–642. <https://doi.org/10.18178/ijiet.2023.13.4.1847>
- Purwanto, Hamdan, A., Putra, A. K., Aripriharta, Tan, I., & Farihah, S. N. (2024). Geo-Virtual Reality (GVR): The creative materials to construct spatial thinking skills using virtual learning based metaverse technology. *Thinking Skills and Creativity*, 54(November 2023), 101664. <https://doi.org/10.1016/j.tsc.2024.101664>
- Putra, A. K., Sumarmi, Deffinika, I., & Islam, M. N. (2021). The effect of blended project-based learning with stem approach to spatial thinking ability and geographic skill. *International Journal of Instruction*, 14(3), 685–704. <https://doi.org/10.29333/iji.2021.14340a>
- Rock, A. E. (2022). Bringing geography to the community: community-based learning and the geography classroom. *GeoJournal*, 87(s2), 235–247. <https://doi.org/10.1007/s10708-021-10408-3>
- Segara, N. B., Maryani, E., Supriatna, N., & Ruhimat, M. (2018). Investigated the Implementation of Map Literacy Learning Model. *Geosfera Indonesia*, 3(2), 146. <https://doi.org/10.19184/geosi.v3i2.7808>
- Silviariza, W. Y., Sumarmi, & Handoyo, B. (2020). Using of Spatial Problem Based Learning (SPBL) model in geography education for developing critical thinking skills. *Journal for the Education of Gifted Young Scientists*, 8(3), 1045–1060. <https://doi.org/10.17478/JEGYS.737219>
- Tomaszewski, B., Walker, A., Gawlik, E., Lane, C., Williams, S., Orieta, D., McDaniel, C., Plummer, M., Nair, A., Jose, N. S., Terrell, N., Pecsok, K., Thomley, E., Mahoney, E., Haberlack, E., & Schwartz, D. (2020). Supporting disaster resilience spatial thinking with serious GeoGames: Project Lily Pad. *ISPRS International Journal of Geo-Information*, 9(6). <https://doi.org/10.3390/ijgi9060405>
- Virranmäki, E., Valta-Hulkkonen, K., & Pellikka, A. (2021). Geography Curricula Objectives and Students' Performance: Enhancing the Student's Higher-Order Thinking Skills? *Journal of Geography*, 120(3), 97–107.



<https://doi.org/10.1080/00221341.2021.1877330>

von Reumont, F., & Budke, A. (2021). Spatial Thinking With Comics in Geography Education. *Frontiers in Education*, 6(August), 1–16. <https://doi.org/10.3389/feduc.2021.702738>

Wahelo, T. T., Mengistu, D. A., & Merawi, T. M. (2025). Geography teachers' implementation of problem-based learning for deforestation and climate change education in Metekel Zone Secondary Schools, Northwest, Ethiopia. *International Journal of Educational Development*, 117(May), 103314. <https://doi.org/10.1016/j.ijedudev.2025.103314>

Wijayanto, B., Sumarmi, Utomo, D. H., Handoyo, B., & Aliman, M. (2023). Problem-Based Learning Using E-Module: Does It Effect on Student'S High Order Thinking and Learning Interest in Studying Geography? *Journal of Technology and Science Education*, 13(3), 613–631. <https://doi.org/10.3926/jotse.1965>

Wilby, R. L., & Esson, J. (2024). AI literacy in geographic education and research: Capabilities, caveats, and criticality. *Geographical Journal*, 190(1), 1–8. <https://doi.org/10.1111/geoj.12548>

