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Bridging Pedagogy and Place: How Teachers Use Geospatial Technologies to Rethink Geography Learning

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ABSTRACT
This research explores geospatial technology as a pedagogical tool in geography education. This research focuses on the types of geospatial technologies, instructional strategies, learning models, and pedagogical approaches applied. **Methods**: A Systematic Literature Review was used following Booth et al. (2016) and utilizing the PRISMA protocol. Eight peer-reviewed empirical studies published between 2020 and 2025 were selected using strict inclusion criteria. **Results**: ArcGIS Online and QGIS tools were the most commonly used technologies. Teachers implemented inquiry-based strategies, such as structured and guided inquiry, supported by learning models including Project-Based Learning, Inquiry-Based Science Education, and Problem-Based Learning. Pedagogical approaches emphasized student-centered, contextual, and transformative learning. **Implications**: The findings highlight the need for supportive curricula and teacher training. This study contributes to GI-Pedagogy and G-TPACK theory and recommends expanding future research to include non-English sources and broader datasets. **Additional materials**: This paper includes 19 references, 2 analytical tables, 1 figure, and no graphs, appendices, or test instruments.

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INTRODUCTION

In the context of 21st-century education, the integration of technology into teaching and learning has become a strategic imperative. Among the emerging technologies, geospatial technology—encompassing Geographic Information Systems (GIS), remote sensing, and spatial data analysis—has demonstrated significant potential to enrich geography education. As a discipline fundamentally concerned with spatial relationships, human-environment interactions, and locational analysis, geography is inherently aligned with geospatial thinking (Fu, 2020).

Empirical research has increasingly shown that the use of geospatial technology in classrooms not only enhances students' understanding of geographic concepts but also fosters the development of spatial reasoning and technical skills (De Miguel González & De Lázaro Torres, 2020; Jadallah et al., 2017; Metoyer & Bednarz, 2017; Santoso et al., 2021). At various educational levels, such as primary and secondary schools, studies have reported improvements in students' ability to analyze maps (Jadallah et al., 2017), increased technological literacy (Azevedo et al., 2016), and better comprehension of spatial relationships in geographic content (Metoyer & Bednarz, 2017).

Several recent studies have also explored the pedagogical implementation of geospatial technologies in school contexts. For example, Mašterová (2023) emphasized the importance of using an inquiry-based approach when integrating Geospatial Science and Technology (GST), while Schulze (2021) analyzed internal

and external factors affecting the effectiveness of GIS-based learning methodologies. Likewise, McLaughlin and Bailey (2023) demonstrated how geoscience interventions can develop students' spatial skills. Meanwhile, Berhauserova identified institutional and instructional barriers to GIS integration, and Konstatakos proposed an analytical framework for evaluating its effectiveness in geography and environmental learning. However, despite the richness of these studies, Bondarenko (2025) noted that instructional strategies, learning models, and pedagogical approaches for GIS-based learning have not yet been systematically classified or analyzed.

This gap indicates a critical need for further investigation, particularly regarding how geography teachers can adapt and apply appropriate pedagogical strategies to implement geospatial technology in the classroom effectively. While the technical benefits of geospatial tools are well documented, limited research has systematically examined the pedagogical dimension—namely, how teachers select, modify, or design learning models and instructional methods that align with curricular goals and student needs.

Therefore, this study aims to investigate the application of geospatial technology in geography education, specifically focusing on the types of technology used, the instructional strategies and pedagogical models adopted, and the extent to which teachers adapt these elements to support meaningful learning. This study seeks to make a strong empirical and systematic contribution to the field by bridging the gap between theoretical frameworks and practical implementation. The unique contribution lies in analyzing the pedagogical adaptability of geography teachers, rather than merely evaluating the tools' effectiveness. The findings are expected to support teacher professional development, inform curriculum design, and guide education policy about the digital transformation of geography education.

METHODS

This research uses a Systematic Literature Review approach that refers to the stages of Booth et al. (2016). This process includes five stages, namely: (1) determining the scope; (2) selecting articles; (3) assessing the quality; (4) extracting and analyzing data; (5) presenting findings. This study examines how geospatial technology is integrated as a pedagogical tool in geography learning. With a limited focus on: (1) geospatial technologies are used in geography learning by teachers in various studies; (2) instructional strategies reported by teachers in using geospatial technologies; (3) learning models applied to support the integration of these technologies; (4) pedagogical approaches used in the context of geography learning.

Articles were selected through inclusion criteria, namely: (1) articles had to address geography teachers, both in-service and pre-service; (2) articles had to involve the use of geospatial technologies, such as GIS or others; (3) articles had to describe the transformation of pedagogical practices, in terms of instructional strategies, learning models, and teaching approaches; (4) only empirical studies were accepted, whether using qualitative, quantitative, or mixed-methods; (5) articles had to be published within 2020 to 2025 and written in English. Studies that did not meet these criteria, including those that were not peer reviewed, book reviews, book chapters or books, and were not relevant to the focus on teachers, or were theoretical without practical implementation, were excluded from the analysis.

Article searches were conducted through two main databases, Scopus and Semantic Scholar. To expand the range of literature, the Publish or Perish tool was also used. The keywords used in the search included "geospatial technology", "GIS", "geographic information system", "teacher", "geography teacher", "pedagogy", "teaching strategy", "instructional model", and "pedagogical practice". Keyword combinations were assembled using Boolean operators: ("geospatial technology" OR GIS OR "geographic information system") AND (teacher OR "geography teacher") AND ("pedagogy" OR "teaching strategy" OR "instructional model" OR "pedagogical practice"). And the study selection process follows the PRISMA flow which includes four main stages identification, screening, eligibility assessment, inclusion. This process was conducted using Covidence to assist with data management.

RESULTS AND DISCUSSION

From the search results shown in Figure 1, 45 articles were found (10 from Scopus and 35 from Semantic Scholar). After the removal of six duplicates (2 manually and 4 automatically by Covidence), the remaining 39 articles were filtered by title and abstract. As a result, 19 articles were eliminated because they did not meet the criteria. Next, 20 articles were analyzed in full. At this stage, 12 articles were excluded because they were not written in English (2 articles), published before 2020 (1 article), not relevant to the focus of the study (8 articles), and did not discuss geography teachers (1 article). Meanwhile, the final 8 selected articles met the inclusion criteria.

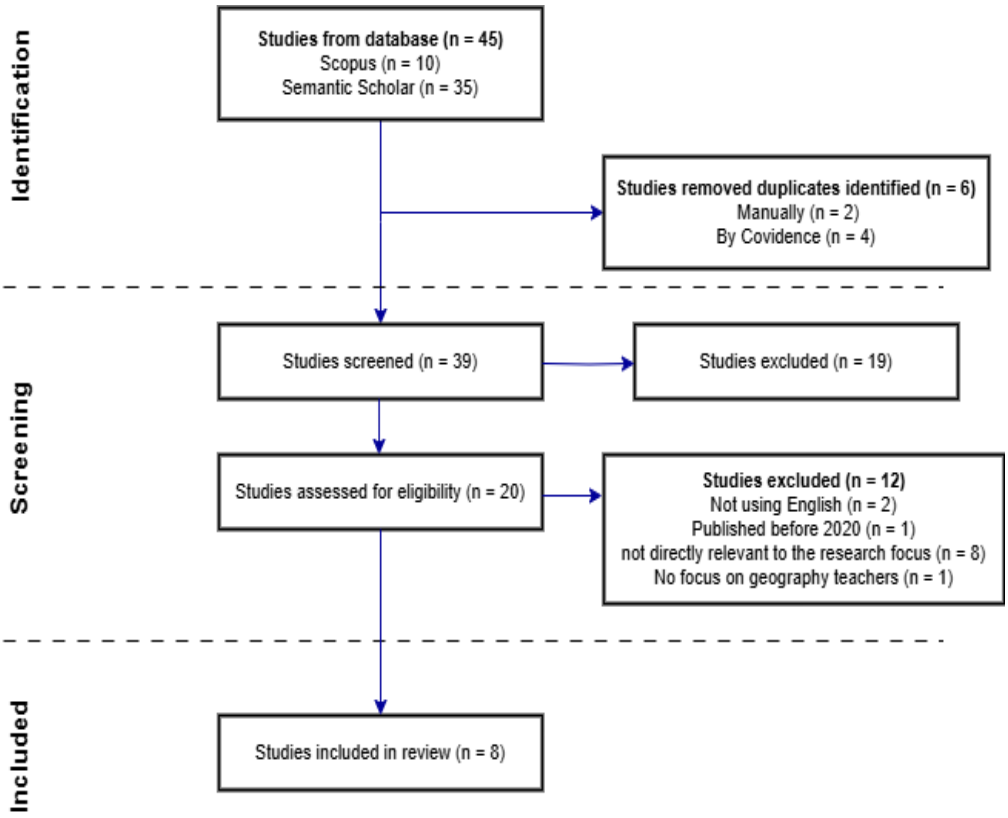

Figure 1. Study screening stages using PRISMA

The selected studies show how geospatial technologies are integrated as pedagogical tools in geography learning. The results presented in Table 1 are synthesized thematically based on the main focus.

Table 1. Synthesis of Selected Studies

Author (Year)	Country	Geospatial Technology	Instructional Strategy	Learning Model	Pedagogical Approach
Brown et al. (2024)	Ireland	ArcGIS Online, and StoryMaps	Inquiry-Based	Project-Based Learning	Place-Based Learning
	Finland	ArcGIS Online (StoryMaps)	Differentiated Instruction	Design-Based Research	Student Centered
Anunti et al. (2020)	South Korea	Geospatial Web Services (GWS)	Structured Inquiry	Inquiry-Based Science Education	Data-Driven
	Spain	ArcGIS Online, StoryMap, Survey123	Explicit Instruction	GI-Pedagogy	Transformative Pedagogy

Lee et al. (2025)	United States	ArcGIS Online	Guided Inquiry	Geospatial-Inquiry Cycle	Situated Learning
	Turkey	QGIS	Dick & Carey Systems Model	TPACK-Based Professional Development	Constructivist Pedagogy
Puertas-Aguilar et al. (2022)	South Africa	QGIS, OpenStreetMap (OSM)	Demonstration Strategy	Project-Based Learning	Experiential Learning
	Italy	Copernicus Data, Sentinel Satellite Imagery, Earth Observation GIS Tools	Co-Creation Inquiry Tasking	Inquiry-Based Science Education, Problem-Based Learning	STEAM Pedagogy

Table 1 shows key findings highlighting geospatial technology. For example, ArcGIS Online emerged as the most popular GIS product (4 out of 8 studies), with QGIS as an open-source substitute. Other tools, including Survey123, OpenStreetMap, ArcGIS StoryMaps, and Geospatial Web Services, were also utilized. With learning methods ranging from project-based learning to inquiry-based science education and problem-based learning, an inquiry-based approach dominates learning strategies. Student-centered, context-based, transformative, and collaborative pedagogies are common instructional approaches.

Geospatial Technology Integration in Geography Learning

Brown et al. (2024) illustrated ArcGIS Online and StoryMaps integrated in Project-Based Learning to develop a cross-disciplinary module oriented to the SDGs. Students investigate local and global issues through data-driven spatial narratives, while teachers connect the national curriculum to real-world contexts. This effort was made to foster scientific literacy and critical thinking skills. This finding is reinforced by the study of Anunti et al. (2020) In Finland, ArcGIS StoryMaps was used to support digital portfolio-based learning through differentiated instruction using the Design-Based Research model. Another study also showed that integrating geospatial technology in disaster education with Geospatial Web Services helped students analyze data and make decisions based on flood, earthquake, and landslide data. Inquiry-Based Science Education strengthened multi-scale spatial reasoning and data-driven argumentation (Lee et al., 2025). In addition, integration is also emphasized in the context of sustainability, where students use ArcGIS Online, Survey123, and StoryMap for their thematic assignments connected to global and local issues. This pedagogical approach draws on Rosenshine's principles and is developed in the GI-Pedagogy model, which involves sustainability, ethical, and affective aspects in learning (Puertas-Aguilar et al., 2022).

Whitworth et al. (2022) utilized ArcGIS Online to train instructors in Guided Inquiry utilizing the Geospatial-Inquiry Cycle model with a Situated Learning approach. The model is implemented from question formulation to presenting spatial visualization outcomes. Yildirim & Ünlü (2021) used QGIS through the Dick & Carey System, as well as the G-TPACK model and a Constructivist approach, to develop teaching abilities. In addition, Fleming & Evans (2021) studied in Africa using QGIS and OpenStreetMap through a demonstration of project-based learning on local issues with a hands-on approach. Meanwhile, the great potential of geospatial technologies such as remote sensing was utilized by Vernile et al. (2021) with Sentinel-2 data through Co-Creation Inquiry Tasking in the GIS4Schools program. Inquiry-Based Science Education (IBSE) and Problem-Based Learning integration through collaborative tasks, students map, analyze, and find solutions to local environmental issues. The STEM approach used was shown to strengthen spatial, digital and scientific literacy while fostering climate awareness.

Geospatial Technologies Used

ArcGIS Online remains the most commonly used platform in the field (Anunti et al., 2020; Brown et al., 2024; Puertas-Aguilar et al., 2022; Whitworth et al., 2022), thanks in part to its compatibility with tools like StoryMaps and Survey123. Meanwhile, QGIS is gaining traction as a strong open-source alternative (Fleming & Evans, 2021; Yildirim & Ünlü, 2021). Additionally, remote sensing data has been increasingly applied to climate change research (Vernile et al., 2021), while Geospatial Web Services (GWS) are being used for real-time disaster risk analysis (Lee et al., 2025).

Instructional Strategies Applied

Inquiry-based instructional strategies are most widely used, ranging from structured inquiry (Lee, 2025) to guided inquiry (Whitworth et al., 2022) and co-creation inquiry (Vernile et al., 2021). These strategies allow students to construct questions, explore spatial data, and actively construct understandings and solutions. Other instructional strategies that emerged are explicit instruction (Puertas-Aguilar et al., 2022), demonstration strategy (Fleming & Evans, 2021), differentiated instruction (Anunti et al., 2020), and Dick & Carey Systems suitable for training (Yildirim & Ünlü, 2021).

Learning Models that Support Geospatial Technology Integration

Various identified learning models emerged that were consistent with active and constructive principles. Project-Based Learning (Brown et al., 2024; Fleming & Evans, 2021), Inquiry-Based Science Education (Lee et al., 2025; Vernile et al., 2021), Design-Based Research (Anunti et al., 2020). Other models, such as GI-Pedagogy and G-TPACK, present integrating technology, pedagogy, and geographic content to support meaningful geography learning (Puertas-Aguilar et al., 2022; Yildirim & Ünlü, 2021).

Pedagogical Approach Used

Almost all studies emphasize student-centered and contextualized pedagogical approaches. Place-Based Learning (Brown et al., 2024), Situated Learning (Whitworth et al., 2022), and Experiential Learning (Fleming & Evans, 2021), Transformative Pedagogy (Puertas-Aguilar et al., 2022), STEAM Pedagogy (Vernile et al., 2021), and Constructivist Pedagogy, which emphasizes the active experience of teachers to contextualize learning by using technology (Yildirim & Ünlü, 2021).

Theoretical Implications

The findings of this study contribute theoretically to the development of geography pedagogy and technology-based education. Geospatial technology has proven itself not only as a mapping tool, but also as a pedagogical tool that encourages active, constructive, and contextualized student engagement. This has expanded the Technological Pedagogical Content Knowledge (TPACK) framework, emphasizing the importance of mastering spatial data-based inquiry, problem-solving, and decision-making strategies in the use of geospatial technology (Whitworth et al., 2022; Yildirim & Ünlü, 2021).

On the other hand, the findings of this study also enrich Inquiry-Based Learning and constructivism theories by showing how geospatial technology is integrated in the learning process to support data exploration, critical reflection, and deep conceptual understanding. In geography education, the spatial elements and locality inherent in the use of geospatial technology make place-based learning and situated learning approaches increasingly relevant for developing students' geographic literacy (Brown et al., 2024; Fleming & Evans, 2021). In addition, the presence of GI-Pedagogy and G-TPACK models that integrate themselves with STEAM principles also contributes significantly to strengthening pedagogical approaches in an interdisciplinary and contextual manner. This approach highlights the importance of paying attention to the affective, ethical, and sustainability dimensions of learning, in line with transformative learning theory that emphasizes changing ways of thinking and acting through direct engagement with real-world problems (Puertas-Aguilar et al., 2022; Vernile et al., 2021). Furthermore, this study contributes to the understanding of professional learning theory in strengthening teacher capacity. This confirms that strengthening teacher skills

in the digital era is not only required related to technical skills, but deep pedagogical and conceptual abilities are also needed (Anunti et al., 2020; Whitworth et al., 2022).

Practical and Policy Implications

The findings of this study have implications for geography learning practices and education policy in the digital era. Studies show that the integration of geospatial technologies has an impact in strengthening students' spatial, digital, and scientific literacy (Brown et al., 2024; Lee et al., 2025). Teachers can use platforms such as ArcGIS Online, QGIS, and Sentinel-2 remote sensing data to design assignments that link local and global issues (Puertas-Aguilar et al., 2022; Vernile et al., 2021). This has the potential to foster 21st-century skills (Anunti et al., 2020; Fleming & Evans, 2021) such as critical thinking, problem solving, and collaboration. QGIS and OpenStreetMap are feasible in areas with limited digital infrastructure, with adequate technopedagogical notes (Yildirim & Ünlü, 2021).

From a policy perspective, these findings point to the importance of integrating geospatial literacy into the national curriculum, both within geography and across disciplines. Spatial data-based competency standards and mastery of inquiry are also important in education to adapt to global challenges (Lee et al., 2025; Puertas-Aguilar et al., 2022). In addition, teacher training needs to be formulated, the Geospatial Inquiry Cycle model (Whitworth et al., 2022) and the G-TPACK-based instructional design approach (Yildirim & Ünlü, 2021) can be a framework to improve teacher capacity both technically, pedagogically, and conceptually. This platform of open resources and data-driven innovation is an important foundation in transforming education towards a more adaptive and sustainable future.

Limitations

This study has some limitations it only includes research written in English, focuses on studies published between 2020 and 2025, and relies on just two databases. Because of these restrictions, the findings may not fully reflect the broader landscape of available research. These gaps highlight opportunities for future studies to broaden the scope by incorporating literature in other languages, covering a wider publication range, and utilizing additional databases.

CONCLUSION

This study reveals that geospatial technologies have evolved into effective tools for active, data-driven, and context-based learning. Reviewing eight studies, it highlights how educators use ArcGIS Online, QGIS, and remote sensing to engage students with real-world issues. These tools enhance spatial literacy, critical thinking, and understanding of geographical concepts. Applied through project-, inquiry-, and problem-based learning, the pedagogy reflects a constructivist approach. However, the study is limited to English-language sources. Broader research is needed to capture global perspectives on geospatial integration.

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