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Google Earth as a catalyst for spatial problem-based learning in enhancing spatial thinking skills

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Abstract

This study investigated the effectiveness of integrating Google Earth into Spatial Problem-Based Learning (SPBL) as a means of enhancing students' spatial thinking skills within the context of geography education. Traditional instructional methods often fall short of developing these critical competencies, particularly for complex topics such as watershed systems. Employing a quasi-experimental design, this research involved two purposively selected groups of high school students: an experimental group exposed to Google Earth-assisted SPBL and a control group receiving conventional direct instruction. Data collection was conducted through spatial thinking ability tests administered in pre-test and post-test formats. The data were analyzed using the non-parametric Mann-Whitney U test to determine significant differences between the two groups. The results revealed that students in the experimental group exhibited statistically significant improvements in spatial thinking skills compared to those in the control group. These findings underscore the pedagogical value of integrating geospatial technologies such as Google Earth in fostering students' spatial reasoning, visualization, and analytical abilities in geography learning. This research contributes to the growing body of knowledge advocating for technology-supported, inquiry-based instructional models and offers empirical evidence for adopting SPBL integrated with geo-visualization tools to promote higher-order thinking in spatially complex subjects. Implications suggest that incorporating such digital platforms in educational settings can cultivate students' capacity to analyze, interpret, and solve real-world environmental problems, thereby strengthening geography education through experiential and technologically enriched learning approaches.

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Keywords: *spatial problem-based learning; Google Earth; spatial thinking.*

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INTRODUCTION

Students' low spatial thinking skills present a critical barrier in Indonesian geography education, a weakness rooted in the dominance of conventional, teacher-centered instruction. This pedagogical gap cripples' students' capacity to analyze complex socio-ecological systems, an essential competency for confronting the nation's pressing environmental challenges. For instance, watershed management, a geographical issue impacting ecological stability and millions of livelihoods, demands the very systemic and spatial thinking that remains underdeveloped in schools. Without transformative pedagogical interventions, equipping the younger generation to contribute actively to environmental conservation efforts remains a rhetorical exercise (Rizal et al., 2022). This demonstrates a critical disconnect: while urgent environmental challenges demand spatial thinking, the prevailing pedagogy actively fails to develop it, necessitating transformative instructional intervention.

Amidst the demand for 21st-century competencies, digital learning offers more than content access; it is an arena for cultivating higher-order cognitive attributes, such as critical thinking and complex problem-solving (Silber-Varod et al., 2019; Syaibana et al., 2022)In geography education, developing spatial thinking is not merely a curricular goal but a direct response to the shortcomings of conventional instruction. This competency is fundamental for interpreting multifaceted spatial phenomena, including complex hydrological systems. In geography education, spatial thinking stands as a core competency, fundamentally required to interpret multifaceted spatial and environmental phenomena, including intricate hydrological systems (Liu et al., 2019; Putra et al., 2022). Therefore, cultivating spatial reasoning is not merely a curricular goal but a foundational pillar for fostering environmental awareness and societal preparedness (Arifka et al., 2021; Putra et al., 2023).

To this end, the integration of geospatial technologies, such as Google Earth and Geographic Information Systems (GIS), has become a prominent pedagogical strategy. These tools can transform classrooms into immersive learning environments where students can directly engage with real-world data (Ciarli et al., 2021; Singleton & Arribas-Bel, 2021). Its intuitive three-dimensional visualizations, in particular, provide a tangible experience of spatial phenomena, a feature critically absent in text-based instruction. However, the true potential of such a powerful tool is unlocked only when it is embedded in a structured pedagogical model. A framework such as Spatial Problem-Based Learning (SPBL) is therefore essential to elevate its use from passive observation to active inquiry, guiding students to leverage rich visual data for genuine geospatial reasoning and problem-solving. Google Earth is particularly valued for its accessibility and intuitive three-dimensional visualizations. Its potential lies not only in visualization but also in its capacity to support specific instructional models, such as Spatial Problem-Based Learning (SPBL). SPBL provides a framework that pushes students toward inquiry and contextual exploration (Alfatikh et al., 2020), an approach whose potential is increasingly explored for applying geospatial reasoning in authentic scenarios (Afifah et al., 2024).

However, a significant gap exists between the theoretical potential and practical implementation of these technologies. For instance, while Zhao et al. (2021) provide compelling evidence that Google Earth's 3D visualization features can significantly enhance students' understanding of terrain and landforms, their study also implicitly suggests that these benefits are contingent on careful instructional design. This finding resonates with the broader implementation challenges identified by Dinc (2019), who highlighted time constraints and teachers' low techno-pedagogical proficiency as key barriers to effective adoption. This challenge is amplified when applied to complex topics, such as watershed analysis. Conventional didactic teaching on this topic has proven inadequate, as it often results in rote learning and fails to build higher-order spatial reasoning skills (Ali et al., 2024). Therefore, the critical research gap is not whether technology such as Google Earth is useful, but how it can be effectively operationalized. The challenge lies in designing an instructional model like SPBL that simultaneously leverages the tool's visualization strengths (as shown by Zhao et al., 2021) while mitigating its documented implementation barriers (as cautioned by Dinc, 2019), particularly for teaching complex watershed concepts (Putra et al., 2021; Salsabila & Putra, 2024).

The SPBL model provides a robust pedagogical framework grounded in Bruner's discovery learning theory, which posits that experiential exploration catalyzes the construction of meaningful knowledge (Lombardi & Shipley, 2021). However, a review of the current literature reveals that research on SPBL and geospatial technologies has proceeded along two largely separate streams of inquiry. The first focuses on the SPBL model as a pedagogical framework, often in technology-agnostic contexts. An analysis of the current literature indicates that research on SPBL and geospatial technologies has proceeded along two largely separate streams of inquiry. The first stream focuses on the SPBL model as a conceptual framework, demonstrating its effectiveness in fostering cognitive engagement, real-world problem-solving, and the synthesis of geographic knowledge (Duarte et al., 2022; Hsbollah & Hassan, 2022; Sura, 2023). The second stream investigates tools such as Google Earth, highlighting their technical affordances for 3D visualization but often without integrating them into a structured, problem-based pedagogical model; these studies are often technology-agnostic or apply SPBL in non-geospatial contexts. The second stream, in parallel, investigates tools like Google Earth, highlighting their technical affordances for 3D visualization but often without integrating them into a structured, problem-based pedagogical model (e.g., Zhao et al., 2021). Consequently, despite their strong theoretical promise, there remains a notable scarcity of empirical studies that systematically test their integration, particularly for critical environmental topics such as watersheds, and while the synergistic potential between SPBL and Google Earth is theoretically promising, there is a scarcity of empirical studies that systematically integrate the two. This scarcity is particularly critical in the context of environmental and disaster education, such as watershed topics (Saputro et al., 2023). Therefore, the urgency of this research is not merely normative but is based on an observable gap in the research landscape: the need to bridge the divide between pedagogical innovation (SPBL) and technological tools (Google Earth) within a coherent and tested instructional design.

Previous research has established the independent efficacy of both SPBL and geospatial tools. However, a significant gap remains in the empirical testing of their integrated application, particularly for spatially complex topics such as watershed education. Although prior studies have documented the independent efficacy of both SPBL and geospatial tools in geography education, limited empirical research has examined their integrated application in the context of watershed education, a subject inherently rich in spatial complexity (Carrió Llach & Llerena Bastida, 2023). Furthermore, the experiential dimensions of such an implementation from student and teacher perspectives are rarely explored in the literature. Therefore, a study is warranted to rigorously assess the impact of an integrated SPBL-Google Earth model and to understand its practical classroom dynamics. Additionally, existing literature rarely explores the experiential dimensions of implementing such tools from the perspectives of students and educators. To address this gap, the present study employed a quasi-experimental design to rigorously assess the impact of SPBL supported by Google Earth on students' spatial thinking outcomes in comparison to conventional instructional methods (Wijayanto et al., 2023).

To address this gap, this study systematically evaluated the effectiveness of a Google Earth-based Spatial Problem-Based Learning (SPBL) model in improving high school students' spatial thinking skills within the instructional context of watershed systems. Specifically, this study seeks to answer the following research questions. To address the identified research gap, this study aims to systematically evaluate the effectiveness of a Google Earth-based Spatial Problem-Based Learning (SPBL) model in enhancing high school students' spatial thinking skills within the instructional context of watershed systems. Specifically, this study seeks to answer the following research questions. 1) To what extent does the Google Earth-based SPBL model improve students' spatial thinking skills compared with conventional teaching methods? 2) How do students experience and make meaning of their learning when using a Google Earth-based SPBL model to solve watershed-related problems? and 3) What are the implementation challenges and affordances perceived by teachers when applying the Google Earth-based SPBL model in high school geography classrooms?

METHOD

Research Design

This study employed a quasi-experimental pretest/post-test control-group design to evaluate the effectiveness of the Google Earth-based SPBL model. Two intact senior high school classes were involved: one class was assigned to the experimental group (n=30) receiving the SPBL intervention, and the other to the control group (n=30) receiving conventional instruction. At the outset, both groups were administered an identical pre-test to measure their baseline spatial-thinking skills. Subsequently, over four weeks, the experimental group engaged in the SPBL intervention, while the control group covered the same watershed systems topic using conventional, teacher-centered methods. The research timeline was as follows.

1. Week 1. Both the experimental and control groups were administered a pre-test to measure their baseline spatial-thinking skills.
2. Weeks 2 & 3. The experimental group received the SPBL intervention using Google Earth (four 45-minute sessions), whereas the control group received conventional lecture-based instruction on the same watershed material.
3. Week 4. Both groups were administered an identical post-test to measure changes in spatial thinking skills.

Following the intervention period, both groups were administered the same instrument as a post-test to measure changes in spatial thinking skills. The procedural framework of this study is shown in Figure 1.

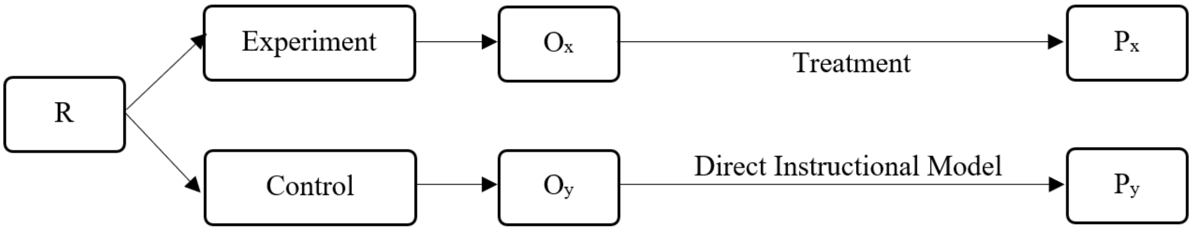

Figure 1. Research design

To assess the statistical impact of the intervention, the following hypothesis was formulated:

H_0 : The SPBL model assisted by Google Earth has no significant effect on the spatial thinking skills of tenth-grade social science students in SMA Ma’arif Lawang.

H_1 : The SPBL model assisted by Google Earth has a significant effect on the spatial thinking skills of tenth-grade social science students in SMA Ma’arif Lawang.

Figure 2 presents an operational flowchart of the research process. It includes stages such as the selection of participants, pre-testing, implementation of learning models, post-testing, and data analysis. This flow sequence ensured the internal coherence of the research procedure and supported the methodological rigor of the intervention evaluation.

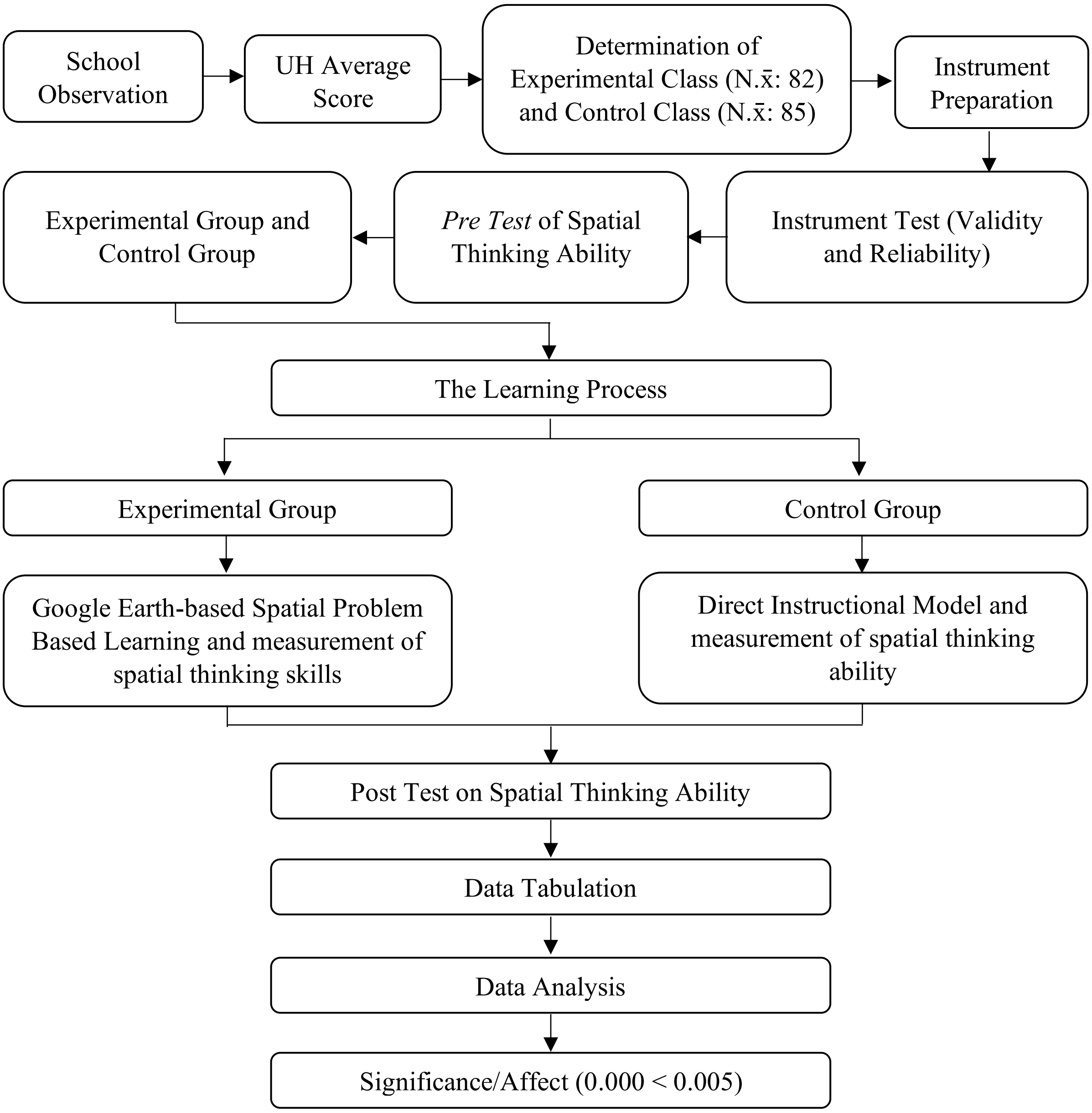

Figure 2. Flow chart of Google Earth-based SPBL implementation in geography education

Research Subjects

The participants were tenth-grade students from two intact social science classes at SMA Ma'arif Lawang in Malang Regency. Intact classes were used due to school administrative policies. Class X IPS-2 was assigned as the experimental group (n=30), receiving the SPBL intervention, while Class X IPS-1 was assigned as the control group (n=30), receiving conventional instruction.

To ensure that the groups were comparable before the intervention, an equivalence test was performed on the pre-test scores of spatial thinking skills. A Mann-Whitney U test revealed no statistically significant difference between the experimental (Mdn = 35.0) and control groups (Mdn = 36.5), U = 418.5, p = .65. This result confirms that both groups possessed a comparable baseline of spatial thinking ability before the study began, thus supporting the internal validity of the findings.

Research Implementation

The research intervention was conducted over two weeks, comprising four 2×45 min class sessions. The treatment for the experimental and control groups was delivered concurrently by the same teacher to ensure consistency. In the experimental group, the teacher acted as a facilitator and guided student inquiries. The students worked in collaborative groups of four, with one laptop per group. The intervention guided the students through the five phases of the SPBL model, as detailed in Table 1. The process began with an orientation to a real-world watershed problem, where students used Google Earth's 3D terrain and street-view features for initial exploration. It then progressed through data collection, where students utilized tools such as Historical Imagery and measurement features, and culminated in a final session where each group presented their analysis and proposed solutions. In contrast, the control group received conventional, teacher-centered instruction, where the teacher acted as a traditional instructor, delivering lectures using PowerPoint and textbooks. The detailed session-by-session schedule and activities for both groups are outlined in Table 1.

Table 1. Research implementation timeline

Meeting	Duration	SPBL Phase (Experimental Group)	Key Activities (Experimental Group)	Key Activities (Control Group)
1	2 × 45 min	Phase 1: Orientation to Problems	• Pre-test administered (first 20 min) • Teacher presents watershed problem video • Group exploration of the watershed in Google Earth	• Pre-test administered (first 20 min) • Teacher delivers a lecture on watershed concepts • Note-taking and initial Q&A.
2	2 × 45 min	Phase 2: Formulating Problems & Phase 3: Collecting Data	• Groups formulate specific spatial problems • Guided data collection using Google Earth's Historical Imagery and measurement tools.	• Teacher continues lecture on watershed issues • Students complete an individual worksheet based on textbook maps.
3	2 × 45 min	Phase 4: Analyzing Data	• Groups analyze collected spatial data to find patterns and impacts of human activity • Teacher facilitates group discussions.	• Teacher reviews worksheet answers • Class-wide discussion led by the teacher.
4	2 × 45 min	Phase 5: Communicating Results	• Each group presents their findings (10 min each) • Class discussion and conclusion • Post-test administered (last 20 min)	• Final review session of all materials • Post-test administered (last 20 min).

Phase 1 (Orientation): This was conducted in the first session after the pre-test. Students, in their groups, used Google Earth's 3D terrain and street-view features to gain initial familiarity with the Welang and Brantas watersheds based on a problem posed by the teacher. *Phase 2 and 3 (Formulation & Data Collection):* During the second meeting, each group articulated a specific spatial question and then used Google Earth tools (e.g., Historical Imagery, line/polygon tools) to collect relevant data on land-use changes, vegetation, and human activity, following a guided worksheet. *Phase 4 (Analysis):* Meeting 3 was dedicated to this phase, where groups synthesized their collected data to assess spatial relationships and infer the causes of environmental changes in the watershed. *Phase 5 (Communication):* In the first half of Meeting 4, each group presented its findings and proposed solutions to its peers. This was followed by the administration of the post-test.

Instrument Test

To assess students' spatial thinking skills, this study employed essay-type test instruments developed in alignment with established spatial thinking indicators as formulated by Lee and Bednarz (2011). The instrument consists of eight open-ended questions administered during both the pre-test and post-test phases. Each item was designed to capture multiple dimensions of spatial cognition and analytical reasoning, ranging from basic identification to higher-order spatial inferences. The formulation of the scoring criteria followed the cognitive levels outlined in Bloom’s taxonomy, ensuring that the measurement of student performance reflected gradations in complexity and depth of thinking.

The validity of the test items was evaluated using Pearson’s product-moment correlation (bivariate Pearson), correlating individual item scores with the total test scores to determine internal consistency. Statistical analysis was conducted using SPSS version 22. According to standard psychometric criteria, items with correlation coefficients (r) greater than 0.30 were considered valid, while those below this threshold were deemed invalid and subsequently excluded from the instrument (Sugiyono, 2019). The calculated r-value of 0.468 confirmed that all the retained items met the validity requirement.

Reliability testing was conducted using Cronbach’s alpha to assess the instrument’s internal consistency. A minimum alpha coefficient of 0.60 was established as the threshold for acceptability. Reliability analysis yielded a Cronbach’s alpha value of 0.920, indicating a high level of internal consistency. This confirmed that the instrument was valid and reliable for measuring the spatial thinking abilities of participating students. All instrument validation procedures were completed before the actual implementation of the research to ensure methodological rigor and data credibility.

Data Analysis

The pre- and post-test data were analyzed using IBM SPSS Statistics 25. The analytical process began with the prerequisite assumption testing. A normality test using the Shapiro-

Wilk method was performed on the scores for both the experimental and control groups. The results indicated that the data were not normally distributed (p < .05), thus violating the assumption of normality required for parametric tests. Furthermore, a homogeneity of variance test using Levene's test showed that the variances between the groups were not homogeneous (p < .05). Given the violation of these key assumptions, the research hypothesis was tested using a nonparametric alternative, the Mann-Whitney U test. This test was used to determine whether there was a statistically significant difference in the post-test spatial thinking skill scores between the experimental and control groups.

In addition to assessing statistical significance, an effect size (r) was calculated to determine the magnitude of the intervention's impact. The effect size was calculated using the formula $r = Z/\sqrt{N}$, where Z is the standardized test statistic and N is the total number of participants. All statistical decisions were based on a significance level (alpha) of .05.

RESULTS AND DISCUSSION

The implementation of the SPBL-Google Earth model demonstrated a significant positive impact on students' spatial thinking performance. As shown in the post-test results, the experimental group achieved a mean score of 83, substantially outperforming the control group's mean score of 50. The Mann-Whitney U test confirmed that this difference was statistically significant across all measured indicators (p < .05), as detailed in Table 3. A breakdown of the scores for each indicator is presented in Table 2.

Table 2. Post-test data processing results

Spatial Thinking Ability Indicator	Experiment		Control	
	Average	**Classification**	**Average**	**Classification**
Comparison	72	Good	40	Very Less
Aura	77	Good	39	Very Less
Region	93	Very Good	83	Good
Hierarchy	77	Good	50	Very Less
Transition	93	Very Good	54	Very Less
Analogy	97	Very Good	85	Good
Pattern	94	Very Good	44	Less
Association	76	Good	68	Sufficient
Average Score	**83**	**Good**	**50**	**Less**

Table 3. Post-test data processing results

Spatial Thinking Ability Indicator	Asymp. Sig. (2-tailed)
Comparison	0.006
Aura	0.000
Region	0.002
Hierarchy	0.006
Transition	0.000
Analogy	0.000
Pattern	0.000
Association	0.004

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The significant outperformance of the experimental group provides strong empirical support for constructivist principles in geography education. Unlike the control group, which received pre-packaged information through lectures (a transmissive model), the experimental group was immersed in a constructivist environment that encouraged active learning. As posited by Bruner's theory of discovery learning—a key tenet of constructivism—students are not passive recipients but active agents in their own learning. Through the SPBL framework, they were required to explore authentic problems, formulate investigative questions, and collaboratively construct spatial meanings from the raw, complex data presented in Google Earth. This process of active knowledge construction is directly reflected in the results of this study. The high scores on higher-order indicators, such as Analogy (M=97) and Pattern (M=94), are not merely a product of better memorization but evidence of students' ability to synthesize information and build complex mental models of the watershed system. They learn by doing and discovering, which is the essence of constructivism. Therefore, the quantitative findings do not just show that one method is better; they validate the theoretical premise that an active, inquiry-based approach is superior to developing deep and durable spatial thinking skills.

One of Google Earth's fundamental contributions is its ability to bridge the gap between abstract geographical concepts and concrete real-world landscapes. In a conventional classroom, a watershed is often taught as a 2D diagram in a textbook, which can be difficult to understand intuitively. However, the immersive 3D visualization feature allowed students to virtually "fly" through valleys, observe slopes, and visually perceive the topographic boundaries of a watershed. This experiential process is likely a key driver behind the high scores on the Analogy (M=97) and Region (M=93) indicators. Students could build a strong mental model of a watershed's structure, directly analogizing the virtual landscape to theoretical concepts and understanding a watershed as a complete, defined region.

Beyond visualization, Google Earth transformed students' roles from passive observers to active investigators through its interactive toolset. Features such as measurement tools (lines and polygons) empower students to see and quantify spatial phenomena, such as measuring the width of a river, calculating the area of deforestation, and marking the locations of industries (Mahat et al., 2023). This active engagement is crucial in the SPBL model and likely contributed to the improvement in the Association (M=76) indicator, where students actively linked human activities (which they mapped themselves) to surrounding environmental impacts. They were no longer merely reading about cause-and-effect relationships; they were measuring them.

The unique ability of Google Earth to incorporate the dimension of time dramatically increases the depth of student analysis. The remarkable improvement in the Transition (M=93) indicator, for instance, can be directly attributed to the 'Historical Imagery' feature. By toggling between satellite images from different years, students no longer simply talked about land use change; they witnessed it firsthand. They can visually track the processes of deforestation, urban expansion, and changes in a river's course over time. This ability to analyze temporal changes is a high-level spatial thinking skill that is nearly impossible to cultivate using static media, such as textbooks (Johnson & McNeal, 2022).

Finally, Google Earth served as a platform for synthesizing multiple layers of spatial information, which is essential for complex geographical analyses. Students did not just view a raw satellite image; they could also overlay other information, such as road networks, place names, and administrative boundaries. This ability to see multiple variables simultaneously trained their capacity to recognize patterns (M=94). For example, they could identify settlement patterns that followed river valleys or agricultural patterns concentrated in fertile lowlands. By facilitating the synthesis of complex information, Google Earth pushed students to think systemically, understanding that a landscape is the result of the interaction of multiple physical and human factors (Duarte et al., 2022).

The findings of this study offer several practical implications for geography educators seeking to move beyond conventional instruction. This model remains adaptable to settings with limited equipment. A teacher can use a single computer and projector to guide the initial problem orientation and data exploration phase for the entire class. Subsequently, students can work in groups analyzing high-resolution screenshots printed from Google Earth, allowing the core inquiry-based principles of SPBL to be maintained, even without one-to-one device access. The framework of the model is also highly flexible for adaptation to other geography topics. For instance, when studying urbanization, students can use the 'Historical Imagery' feature to track city growth over decades. For disaster mitigation, a 3D terrain view is invaluable for identifying landslide-prone areas or simulating potential flood zones. Ultimately, the long-term impact of this model extends beyond improving test scores; by engaging with authentic problems, it fosters critical 21st-century competencies, such as collaborative problem-solving and a more profound ecological awareness, preparing students to be more informed and engaged citizens.

Although the SPBL-Google Earth model demonstrated significant effectiveness, it is important to interpret these findings within the context of several limitations and non-technical factors. First, it is plausible that the 'novelty effect', where student motivation increases due to the introduction of a new technology, may have contributed to their high engagement and performance. Second, successful implementation was heavily reliant on teachers’ proficiency in facilitating an inquiry-based, technology-rich environment; outcomes may vary with different levels of teacher readiness. Third, the limited duration of the intervention (two weeks) means that while the model is effective in the short term, its long-term impact on knowledge retention remains an open question. Finally, the limited sample size (two classes in one school) restricts the generalizability of these findings to a larger population. Acknowledging these limitations provides a more nuanced understanding of the results and highlights clear directions for future research, such as larger multisite studies with longer implementation periods.

CONCLUSION

This study aimed to evaluate the effectiveness of a Spatial Problem-Based Learning (SPBL) model supported by Google Earth in enhancing students' spatial thinking skills. The findings provide clear answers to our research questions: the SPBL-Google Earth model is significantly more effective than conventional instruction in improving spatial thinking, particularly in higher-order indicators such as analogy and pattern recognition. This success stems from the model's ability to transform abstract geographical concepts into concrete, explorable virtual experiences, a process aligned with the constructivist principles of discovery learning.

The primary scientific contribution of this research is the empirical validation of the synergistic integration of inquiry-based pedagogy (SPBL) with immersive geotechnologies. While prior studies have often examined these components separately, this study demonstrates that their combination creates a powerful learning environment that fosters deep conceptual understanding and transferable analytical skills relevant to real-world environmental challenges. However, these findings should be interpreted in light of the limitations of this study. These include the small sample size, short duration of the intervention, and potential influence of the 'novelty effect' on student engagement.

Despite these limitations, this study has clear practical implications for the field. This underscores the need for a pedagogical shift in geography education toward technology-supported, inquiry-driven models. We recommend that educators adopt platforms such as Google Earth not merely as presentation tools but as arenas for student-led discovery. Future research should explore the long-term impact of this model with larger, more diverse samples and across different geographical topics.

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