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GeoSmart Application as a Tool for Interactive Learning: Literature Review Completed with Experiments for Improving Understanding of Geospheric Phenomena in Geography Education

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ABSTRACT

This study creates and tests the GeoSmart app as an interactive learning tool for high school students to understand geospheric phenomena. The research encompassed concept creation, design, material acquisition, assembly, testing, and dissemination. The study involved a planned group of high school students from Tasikmalaya City. We administered questionnaires and comprehension tests both before and after using the app to collect data. The program significantly improved students' understanding of geospheric phenomena. Statistics verified these benefits, showing that GeoSmart's interactive features engage students and help them understand complicated subjects. The findings suggest that the GeoSmart application has considerable potential for broader adoption in geography education, as it effectively enhances both learning quality and student motivation. This study stresses how important technology is in education and suggests more research be done to look into the long-term effects and wider use of GeoSmart apps.

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1. INTRODUCTION

The geosphere, encompassing the lithosphere, hydrosphere, atmosphere, and biosphere, is a fundamental component of geography education due to its profound impact on the physical and social environments that surround us. Many reports relating to this subject have been well-developed (Fauziah *et al.*, 2021; Harith, 2023; Mulyawati & Ramadhan, 2021; Haritha, 2023). A deep understanding of the interactions between geospheric components is crucial for equipping students with the analytical skills necessary to comprehend complex natural phenomena (McLaughlin & Bailey, 2023; Huggett, 2024; Cheng *et al.*, 2022; Mostacedo-Marasovic *et al*. 2023). However, traditional teaching methods often fall short of conveying the complexities of these concepts, highlighting the need for more interactive and effective learning approaches.

Previous studies have shown that in various countries, such as those in Europe, students struggle to understand the interactions among geospheric components, largely due to the lack of interactive learning media (Cheng *et al.*, 2022; Koupatsiaris & Drinia, 2024). In Africa, limited educational resources exacerbate these challenges, leading to a significant gap in understanding between students in urban and rural areas (Mosios *et al*., 2023). Meanwhile, in America and Asia, conventional teaching methods frequently fail to effectively convey the complexity of geospheric content, resulting in a poor understanding of these concepts among students (Nguyen *et al.*, 2024; Gielstra *et al.*, 2024).

Previous research has indicated that application-based learning media can significantly enhance educational outcomes, especially in the context of geography education. Studies have highlighted that applications such as Google Earth and ArcGIS have greatly improved how students interact with geospatial data, fostering a more dynamic and engaging learning environment (Arrasyid *et al.*, 2024). Researchers have observed that mobile applications enhance student engagement and improve their understanding of geographical concepts by enabling real-time exploration and analysis of geospheric phenomena (Alkhezzi & Ahmed, 2020; Hwang *et al.*, 2021).

The integration of these technologies into the curriculum is seen as essential for bridging the gap between theoretical knowledge and practical application, thus promoting a deeper comprehension of complex geospheric processes (Aguilar, 2020). Despite these advancements, some researchers highlight the incomplete understanding of the long-term effects of these technologies, especially in terms of knowledge retention and their application across diverse cultural contexts (Jeong & Hmelo-Silver, 2016). This suggests a need for further research to explore the full potential of application-based learning media in geography education.

Despite the long-standing use of traditional teaching methods in delivering geospheric content, their effectiveness remains questionable, particularly in teaching complex concepts (Kwasnicka *et al.*, 2016; Jaakkola, 2020). Conventional methods cannot often provide an interactive and immersive learning experience, which is essential for a comprehensive understanding of geospheric phenomena (Dolphin, 2016). The reliance on textbooks and lectures as primary teaching tools often fails to adequately illustrate the dynamics and interactions between geospheric components, limiting students' understanding of theoretical aspects and hindering their ability to apply this knowledge in broader contexts (Laufer *et al.*, 2021; Hilton, 2020; Rafiq *et al.*, 2024).

The primary objective of this study is to enhance students' understanding of geospheric phenomena by developing and testing the effectiveness of the GeoSmart application as an interactive learning medium. This application is designed to address the limitations of

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traditional teaching methods by providing an interactive and accessible platform for students, offering a deeper and more engaging learning experience. With features such as simulations, animations, and quizzes, the GeoSmart application aims to improve students' comprehension of geospheric concepts (Newcombe, 2013; McLaughlin & Bailey, 2023).

This study presents several significant contributions to the field of geography education and the use of technology in learning. First, it develops the GeoSmart application as an interactive learning tool designed to overcome the shortcomings of conventional teaching methods, which often fail to effectively convey complex geospheric concepts. Second, the study introduces interactive features such as simulations, animations, and quizzes that are expected to enhance student engagement and deepen their understanding of geospheric phenomena. Third, the study systematically measures the effectiveness of the GeoSmart application by comparing the learning outcomes of students using this application with those taught through traditional methods. Fourth, it promotes innovation in the use of technology as a learning aid, which not only improves the quality of geography education but also encourages the integration of technology into educational curricula worldwide.

This research addresses the urgent need for more innovative and interactive learning approaches in geography education, particularly in understanding complex geospheric phenomena. The significance of this study lies in its potential to introduce technology as a learning aid that not only enhances the quality of geography education but also strengthens students' motivation to learn. In today's digital era, the integration of technology into education is becoming increasingly relevant, and this study can serve as a valuable reference for the development of other interactive learning media, as well as encouraging the integration of technology into educational curricula across different countries.

2. LITERATURE REVIEW

2.1. Interactive Learning

Interactive learning is a pedagogical approach that emphasizes active student engagement in the learning process, where the interaction between students, teachers, and learning materials plays a crucial role (Muir *et al*., 2022; Prince, 2004). Interactive learning is said to enhance information retention and deep understanding through the use of techniques such as discussions, simulations, and educational games (Stull *et al*., 2021). Interactive learning allows students to engage more deeply with the subject matter, which in turn can increase their motivation to learn (Casau *et al*., 2023). The use of technology in geographies, such as interactive digital maps and computer-based simulations, has proven effective in helping students understand complex concepts such as the dynamics of the geosphere (Al-Rahmi *et al*., 2021; Gikas & Grant, 2013).

Technology plays a vital role in supporting interactive learning in the classroom. Digital technology, in particular, enables the creation of dynamic, student-centered learning environments in which students can explore and manipulate information independently (Lin *et al*., 2017; Warschauer, 2007). For example, studies have shown that utilizing technology-based learning tools, such as interactive geography simulations, improves students' comprehension of intricate geospheric concepts (Hover & Wise 2022; Jong *et al*., 2020). Research suggests that integrating technology into interactive learning not only improves student learning outcomes but also supports more adaptive and personalized teaching methods (Macrorie *et al*., 2021).

In the rapidly evolving field of education, traditional teaching methods are increasingly shifting towards more interactive approaches to create more effective learning experiences (Thyssen *et al*., 2023; May *et al*., 2016). **Figure 1** illustrates how students increasingly rely on interactive learning, which emphasizes active student engagement, to deepen their understanding, particularly in the field of geography. This approach encourages students to take an active role in the learning process, which not only enhances learning outcomes but also fosters a deeper comprehension of complex subject matter.

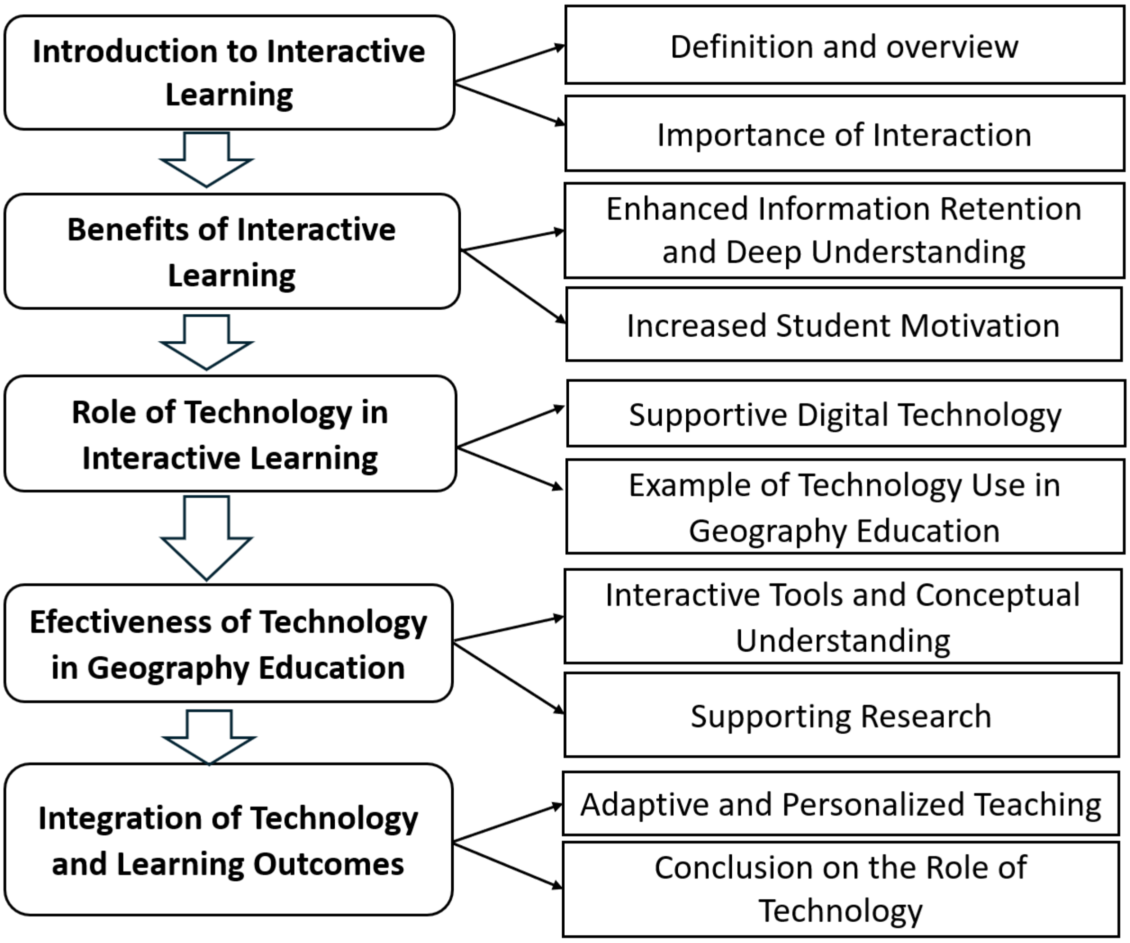

Figure 1. Interactive learning framework.

2.2. Application-Based Learning Media

The advancement of information and communication technology has led to the emergence of application-based learning media, which offer new educational alternatives (Hwang & Tsai, 2011, Baskerville *et al*., 2015). Learning applications designed specifically for mobile and desktop devices provide flexibility for students to learn anytime and anywhere. Applications such as Google Earth and ArcGIS, widely used in geography education, assist students in visualizing geospatial data and comprehending the interrelationships among various geospheric components (Li *et al*., 2022; Janowicz *et al*., 2020). Research indicates that technology-based learning applications can create a rich learning environment and enhance the effectiveness of independent learning (Sung *et al*., 2016; Criollo-C *et al*., 2021).

Learning applications have also played a significant role in bridging the gap between theory and practice in education. Digital devices enable students to access various relevant educational resources, including interactive maps, video tutorials, and computer-based simulations, through these applications (Sung *et al*., 2016). Additionally, learning applications enable teachers to monitor students' progress in real time, providing timely and accurate feedback (Mejbri *et al*., 2022; Harley *et al*., 2017).

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Case studies and related research on the use of technology in geography education have shown significant results in improving students' understanding (Jo *et al*., 2016; Kind, 2009). Research suggests that implementing interactive technology in geography classrooms can enhance student participation and understanding of the material. Additionally, studies have shown that mobile applications in geography education can boost student engagement and offer a more immersive learning experience (Criollo-C *et al*., 2021; Bernacki *et al*., 2020). However, gaps remain unexplored despite extensive research, particularly regarding the long-term effectiveness of using technology in geography education. Research on the long-term effects of technology on knowledge retention and real-world application remains necessary, despite its potential to improve students' understanding in the short term (Jeong & Hmelo-Silver, 2016). Moreover, research on the adaptation of educational technology in various cultural and geographical contexts is also limited, indicating a need for further studies in this area.

The use of application-based learning media has significantly transformed geography education by providing students with flexible, accessible, and engaging tools for deeper learning (Tlili *et al*., 2023). Technologies like Google Earth and ArcGIS enable interactive exploration of geospatial data, bridging the gap between theory and practice. These applications enhance student engagement and independent learning, making education more immersive and effective, as shown in **Table 1**. However, to fully understand their long-term impact on learning retention and application across various educational settings, ongoing research is necessary.

Table 1. Data: Application-based learning media.

No	Learning Application	Description	Devices	Educational Focus	References
1	Mapbox	A customizable mapping application that provides tools for geospatial data visualization and analysis, allowing students to create and interact with their maps.	Mobile, Desktop	Geography, Custom Mapping	(Kang *et al*., 2024; Howland *et al*., 2020)
2	Interactive Maps	Digital maps that provide real-time data, enabling students to explore and understand geographical features interactively.	Mobile, Desktop	Geography, Real-time Exploration	(Roth, 2013)
3	Mobile Learning Applications	General mobile apps are designed to support independent learning by providing access to various educational resources, including videos, quizzes, and interactive content.	Mobile	Geography, Independent Learning	(Arrasyid, *et al*, 2024)
4	Kahoot!	A game-based learning platform that allows students to engage with geography content through interactive quizzes and assessments.	Mobile, Desktop	Geography, Game-based Learning	(Pascu, 2024)
5	Google Earth	A virtual globe that allows students to explore geospatial data in 3D. It helps in visualizing and understanding the interrelationships among geospheric components.	Mobile, Desktop	Geography, Geospatial Visualization	(Zhao *et al*., 2021)

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Table 1 (Continue). Data: Application-based learning media.

No	Learning Application	Description	Devices	Educational Focus	References
6	ArcGIS	A mapping and analytics application that enables the study of geographic information, providing tools to analyze spatial data and comprehend geospheric phenomena.	Mobile, Desktop	Geography, Spatial Analysis	(West & Horswell, 2018)
7	QGIS	An open-source Geographic Information System that enables spatial analysis, geospatial data management, and the creation of interactive maps for educational purposes.	Desktop	Geography, GIS Analysis	(Congedo, 2021)

2.3. Content of Geospheric Phenomena in Geography Education

Geography education plays a critical role in deepening students' understanding of geospheric phenomena, which encompass various aspects of the Earth's physical environment, including the atmosphere, hydrosphere, lithosphere, biosphere, and anthroposphere (Malik, 2018; Agbedahin, 2019; Annan-Diab & Molinari, 2017). These phenomena represent events or occurrences on the Earth's surface that significantly impact human life and other living organisms. This understanding is crucial, as geospheric phenomena play a vital role in sustaining life on Earth and influencing various natural and social dynamics (Chernov & Dudka, 2021). Although this topic has long been a part of the geography curriculum, many studies indicate that traditional approaches often fall short of effectively conveying these complex concepts to students (Salsabila *et al.*, 2022).

The use of interactive learning media, such as the GeoSmart application, has been identified as a potential solution to enhance students' comprehension of geospheric phenomena. Interactive media can help bridge the gap between theory and practice by providing a richer and more contextual learning experience (Manakane & Rakuasa, 2023). Through the use of simulations and visualizations, these applications allow students to observe and interact with digital representations of geospheric processes, thereby increasing their engagement and understanding of the material being taught (Bosker *et al.*, 2010).

Furthermore, technology-based applications like GeoSmart have been shown not only to enhance students' understanding of geospheric phenomena but also to encourage the broader implementation of technology in geography education (Ozdemir & Ozturk, 2022). In these studies, students who utilized interactive applications demonstrated significant improvements in learning outcomes compared to those who employed conventional teaching methods. This indicates that the integration of technology in geography education is not only relevant but also effective in enhancing the overall quality of geography education. **Figure 2** provides a comprehensive visual representation of the geospheric layers, illustrating the interconnectedness between the Earth's physical environments and human activities. This diagram serves as an essential tool to help students better understand the complex interactions among the atmosphere, hydrosphere, lithosphere, biosphere, and anthroposphere, as discussed in this section. By visually mapping these relationships, **Figure**

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2 reinforces the importance of each layer in maintaining the balance of life on Earth, thereby enhancing the educational experience in geography.

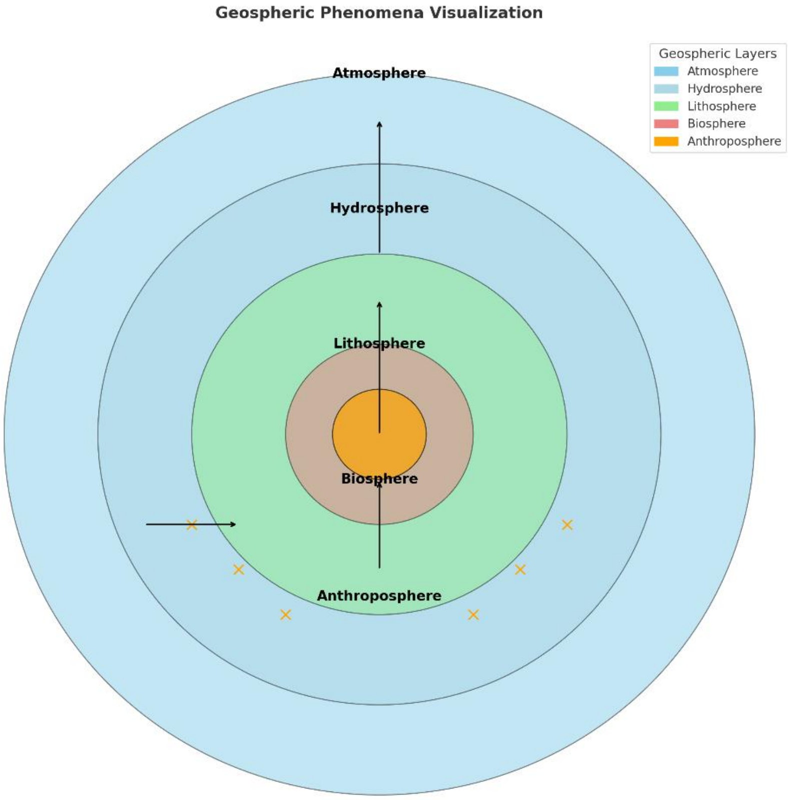

Figure 2. Geospheric phenomena visualization.

Figure 2 illustrates the interconnected layers of the Earth's physical environment, known as geospheric phenomena. The concentric circles represent the atmosphere, hydrosphere, lithosphere, biosphere, and anthroposphere, each playing a crucial role in sustaining life and influencing natural and social dynamics. The outermost circle depicts the atmosphere, gradually transitioning inward through the hydrosphere, lithosphere, and biosphere, with the anthroposphere at the core, symbolizing human activities. Arrows indicate the interactions among these layers, highlighting how atmospheric processes affect the hydrosphere and how human activities impact both the biosphere and lithosphere. This visualization effectively conveys the complexity and interconnectedness of these geospheric components, underscoring the importance of an integrated understanding in geography education. The various learning applications used to enhance understanding of geospheric phenomena in geography education are summarised in **Table 2**. The descriptions in **Table 2** are adapted from various relevant sources (Zhang *et al*., 2007; Bednarz, 2004; Koutsoyiannis, 2020; Şanlı *et al*., 2016; Semmens, 2020).

Table 2 describes a detailed review of geospheric phenomena in geography education, outlining the key components of each layer: atmosphere, hydrosphere, lithosphere, biosphere, and anthroposphere. By highlighting the distinct yet interconnected roles of these layers, the table underscores their collective significance in sustaining life on Earth and influencing natural and social dynamics. Supported by relevant scholarly references, this concise presentation enhances understanding of the complex interactions within the geosphere, serving as a valuable resource for educators and researchers in the field.

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Table 2. Review of geospheric phenomena content in geography education.

No.	Geospheric Phenomena Layer	Components of Each Geospheric Layer
1	Atmosphere	A layer of gases surrounds the Earth, primarily composed of nitrogen (Ni) (78%) and oxygen (O2) (21%). Acts as a shield protecting the planet from harmful solar radiation, such as ultraviolet (UV) rays. Regulates Earth's temperature through the greenhouse effect, enabling a stable climate that supports life.
2	Hydrosphere	Includes all forms of water on Earth: oceans (covering 71% of Earth's surface), rivers, lakes, and groundwater. Plays a vital role in the water cycle, including processes such as evaporation, condensation, and precipitation. Influences weather and climate patterns, and is essential for all known forms of life.
3	Lithosphere	The outermost solid layer of the Earth comprises the crust and the uppermost part of the mantle. Contains tectonic plates, responsible for geological activities such as earthquakes, mountain-building, and volcanic eruptions. Provides a substrate for terrestrial ecosystems and is the source of most mineral resources used by humans.
4	Biosphere	The global sum of all ecosystems where life exists, extending from the deepest ocean floors to the lower atmosphere. Encompasses diverse habitats, including forests, deserts, oceans, and wetlands, each supporting various forms of life. Interacts with other geospheric layers to sustain life, including the exchange of gases and nutrients.
5	Anthroposphere	Represents the portion of the Earth affected by human activities, such as urbanization, agriculture, and industry. Involves the modification of natural landscapes, including deforestation, land-use changes, and the construction of infrastructure.Contributes to environmental changes such as pollution, climate change, and loss of biodiversity.

3. METHODS
3.1. Research Design

This study employs the Research and Development (R&D) method, based on the Luther model (Prayogha & Pratama, 2020; Rawlins & Kehrwald, 2014; Li & Liu, 2023). The Luther model consists of six main stages: concept, design, material collecting, assembly, testing, and distribution. We adapt these stages for the development of the GeoSmart application, an interactive learning tool for understanding geospheric phenomena. The study is designed to develop, test, and evaluate the GeoSmart application, aiming to enhance students' understanding of geospheric concepts at the high school level. **Figure 3** shows a flowchart illustrating the research design process, from development to evaluation of the GeoSmart application.

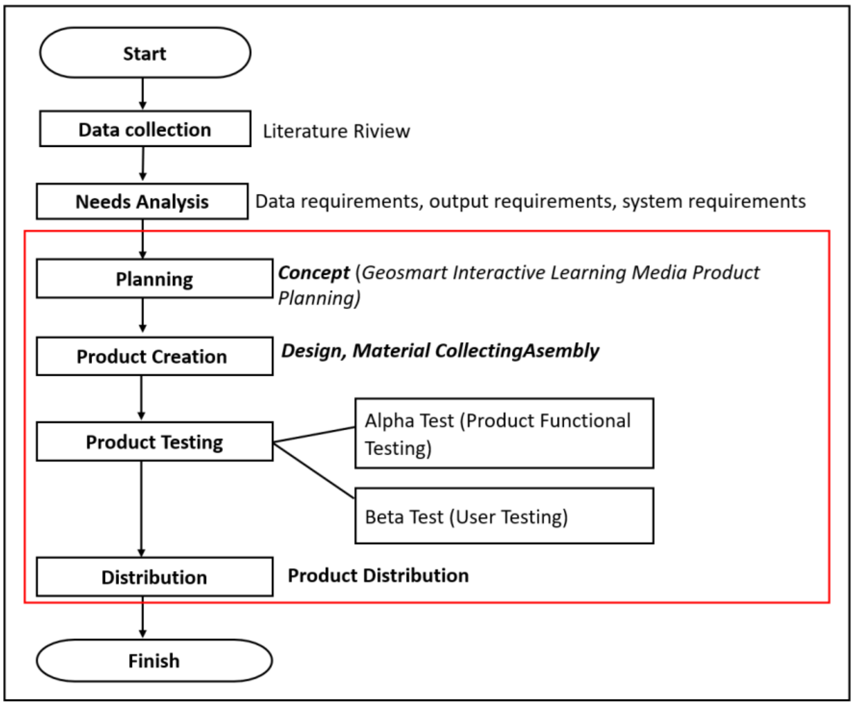

Figure 3. Design science research framework adapted from Luther Model's (Prayogha & Pratama, 2020).

3.2. Population and Sample

The population in this study comprises all high school students in the city of Tasikmalaya, West Java Province, Indonesia. We selected the sample using purposive sampling, concentrating on 11th-grade students studying geography, specifically geospheric phenomena. Students' ability to use information and communication technology, as well as their level of participation in interactive learning, are the sample selection criteria. **Table 3** provides detailed information on the study's population and sample.

Table 3. Population and sample.

School name	Number of Students	Selected Students	Selection Criteria
SMAN 1 Singaparna	150	30	11th Grade, Participative
SMAN 2 Singaparna	180	36	11th Grade, Technologically Adept
SMAN 1 Cikalong	200	40	11th Grade, Participative
	530	106	-

3.3. Data Collection Instruments

The data collection instruments used in this study include questionnaires and comprehension tests. We designed the questionnaire to measure students' perceptions of using the GeoSmart application as an interactive learning tool. It consists of 20 items based on a Likert scale with five response options ranging from "strongly agree" to "strongly disagree." Meanwhile, the comprehension test evaluates how well students understand geospheric concepts both before and after using the GeoSmart application. This test comprises 30 multiple-choice questions developed following the 11th-grade geography curriculum.

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3.4. Research Procedure

The research procedure proceeds through several structured stages. The first step involves the development of the GeoSmart application, which includes needs analysis, application design, material collection, and assembly. A small group of students conducts a pilot test of the developed application to identify and correct any deficiencies.

The next step involves implementing the GeoSmart application in the classroom learning process, known as the main trial. The selected student sample uses this application to study geospheric concepts over a specified period. We collect data through pre- and post-use questionnaires and comprehension tests. After collecting the data, we analyze it to assess the effectiveness of the GeoSmart application in enhancing students' understanding.

3.5. Methods for Analyzing Data

For data analysis, the study used the quantitative descriptive analysis approach. We evaluate the efficacy of the GeoSmart application by analyzing the data obtained from the questionnaires and comprehension tests. We perform a descriptive analysis to evaluate the fluctuations in students' mean understanding scores before and following the program's use. In addition, we conduct inferential statistical analysis, namely t-tests, to assess the significance of the disparities in learning outcomes pre- and after intervention. We use the results of this analysis to evaluate the effectiveness of the GeoSmart application in enhancing students' comprehension of geospheric phenomena.

4. RESULTS AND DISCUSSION

4.1. GeoSmart Application Interactive Media Development Stage

4.1.1. Conceptualization

The GeoSmart application provides unlimited access to multimedia content, including images, videos, and animations, with interactive features such as navigation buttons that ensure smooth scene transitions. The application covers geospheric phenomena and offers Augmented Reality (AR) experiences, educational films, learning videos, polls, and quizzes to create an engaging and immersive learning environment. **Table 3** describes the GeoSmart application as an Android-based educational tool specifically designed to improve 11th-grade high school students' understanding of geospheric phenomena.

Table 3. GeoSmart application's concept.

Component	Description
Title	GeoSmart Application for Android
Content	Geospheric Phenomena
Users	Suitable for ages 12 and above
Duration	Unlimited
Image	It supports the image and animation formats *.png, *.jpg, and *.gif.
Video	Videos in *.mp4 format
Animation	2D animations created using Canva 3D animations created using Assembler
Interactivity	The application integrates navigation buttons for scene transitions and provides explanations of their functions; users can exit the application by pressing the back button on their smartphone.
Features	The platform includes content on geospheric phenomena (lithosphere, pedosphere, hydrosphere, atmosphere, biosphere, and anthroposphere), augmented reality (AR), educational films, learning videos, polls, quizzes (true or false, and multiple choice).

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4.1.2. Design

The design phase consists of two primary stages: the application design, illustrated through a system flowchart, and the storyboard design, which provides a detailed explanation of each flowchart sequence. The design phase begins with the application design. **Figure 4** depicts the GeoSmart application's design as an interactive learning medium, as shown by the system flowchart.

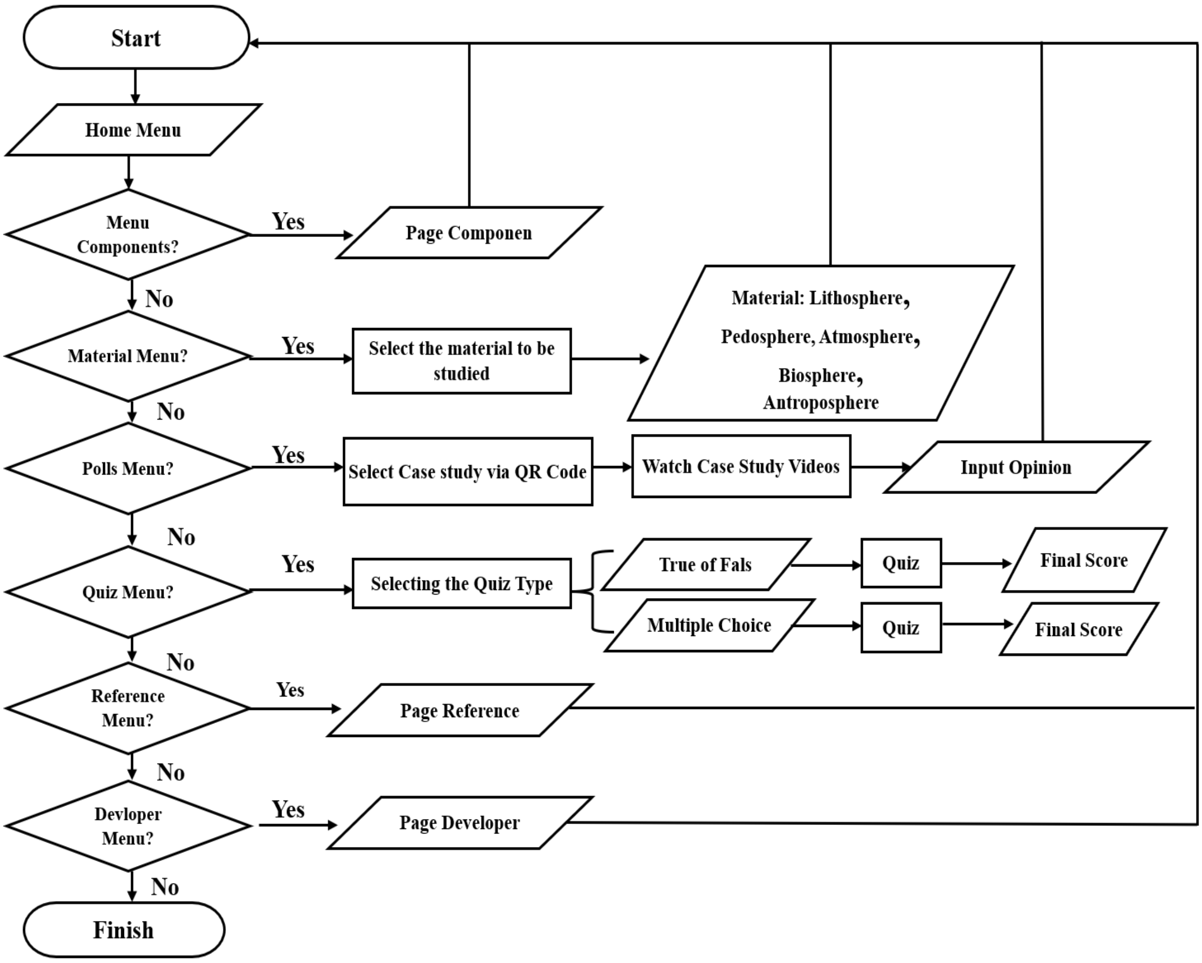

Figure 4. Flowchart GeoSmart application system.

The description of the flowchart is presented in greater detail within the storyboard. The design outputs at this stage are summarized in **Table 4**.

Table 4. The GeoSmart application's brief storyboard.

Scene	Description
Scene 1	The application's entrance screen.
Scene 2	The main menu scene displays the GeoSmart application's primary menu options.
Scene 3	The component menu scene contains phases, learning objectives, and a learning trajectory.
Scene 4	The content menu scene features sub-menus for the lithosphere, pedosphere, hydrosphere, atmosphere, biosphere, and anthroposphere.
Scene 5	The scene under the lithosphere content sub-menu encompasses an introduction, the structure of Earth's layers, rocks, endogenic and exogenic forces, and educational films.
Scene 6	The content scene on endogenic forces provides details about tectonism, volcanism, seismic activity, and augmented reality (AR).

Table 4 (Continue). The GeoSmart application's brief storyboard.

Scene	Description
Scene 7	The pedosphere content sub-menu scene covers an introduction, soil profile, soil types, and soil benefits.
Scene 8	We discuss the hydrological cycle, inland waters, and oceanic waters in the hydrosphere content sub-menu scene.
Scene 9	The atmosphere content sub-menu scene presents an introduction, atmospheric layers, weather and climate, and climate classification.
Scene 10	The biosphere content sub-menu scene provides an introduction, as well as biosphere reserves, flora and fauna characteristics, and biomes.
Scene 11	We explore the anthroposphere content sub-menu scene, which includes an introduction, population composition, population growth, and demographic issues.
Scene 12	The poll menu scene features a QR code to assess users' critical thinking skills.
Scene 13	The quiz menu scene provides two quiz options: true or false, as well as multiple-choice quizzes.
Scene 14	The reference menu scene lists the references and sources used.
Scene 15	The developer menu scene provides information about the application's developers.
Scene 16	The scene contains instructions for using the application's navigation.

4.1.3. Collecting materials

We collected and created the materials for this application in-house. We gathered text and color schemes during this stage. The fonts used in the application are as follows: The title uses Cherry Bomb One with the color code #E5FFE3, the buttons use Brosok with the color code #134757, and the general content uses Tw Cen MT with the color code #000000. The dominant colors used in the application include #6FC6E1, with the background content in.gif and.png formats using the color code #C0E4FF.

We used Canva Pro software to create backgrounds, buttons, and 3D animations as part of the material collection process. The Assembler website also assisted in the development of 3D animation content and augmented reality features. We produced educational videos within the application using two software tools, Canva Pro and CapCut and then published them on the Official GeoSmart YouTube channel.

This research produced quantitative data demonstrating the improvement in students' understanding of geospheric phenomena after using the GeoSmart application. The trials were conducted in two stages, namely alpha and beta testing, with a total sample of 106 students from three high schools in Tasikmalaya City, West Java Province.

4.1.4. Assembly

We conducted the assembly process using Articulate Storyline software, with additional support from the 2APK Builder website. **Figure 5** illustrate the results of this assembly stage.

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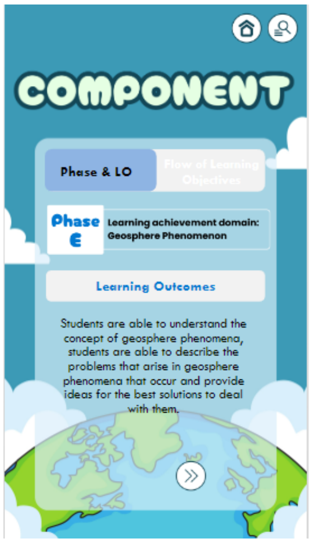
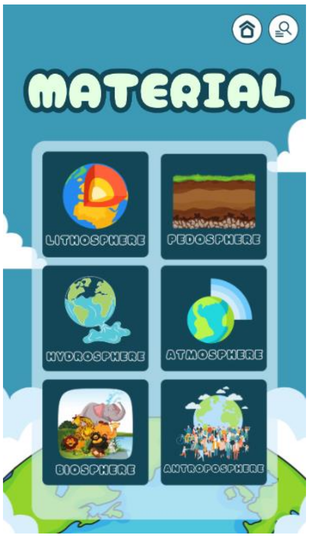
(a) Entry Screen: The initial screen displayed upon launching the application

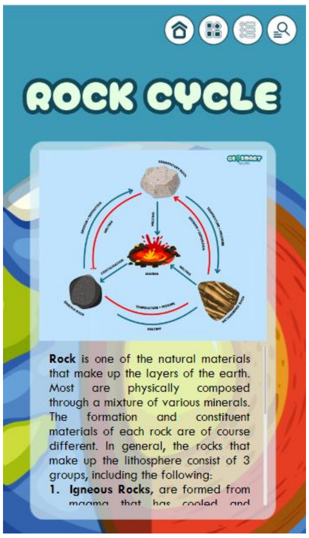
(b) Main Menu: The primary navigation menu provides access to the core features of the GeoSmart app.



(c) Component Menu: The menu shows the different components, such as phases and learning objectives.



(d) Content Menu: The menu provides a list of content categories such as lithosphere and pedosphere.



(e) Lithosphere Content: It displays detailed educational content on the lithosphere, including Earth's structure.

(f) A volcano's augmented reality (AR): We have developed an interactive AR feature that allows users to explore volcanic structures.

Figure 5. Assembly processes and visual descriptions.

4.1.5. Testing

The provided set of questions is designed to progressively challenge students' understanding and critical thinking regarding geospheric phenomena, aligning with different cognitive levels from remembering to creating. The C1 questions focus on foundational knowledge, ensuring that students can recall basic facts about the Earth's structure, atmosphere, and geological processes. For example, identifying the Earth's crust or understanding the main component of the atmosphere tests their ability to retrieve essential information. These questions are crucial as they establish the necessary base of knowledge that students need before they can engage with more complex ideas.

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Moving into C2 and C3, the questions shift towards understanding and applying knowledge, requiring students to explain processes such as volcanic eruptions at tectonic plate boundaries or the role of convection currents in mountain formation. The C3 questions further demand that students use tools like GeoSmart to apply their knowledge practically, such as demonstrating earthquake detection or illustrating the water cycle's impact on soil erosion. These application-based questions are particularly valuable in a geography education context because they encourage students to bridge the gap between theoretical understanding and real-world application, fostering deeper learning.

The C4 questions challenge students to analyze data and make informed conclusions, such as interpreting tectonic plate maps to predict earthquake-prone regions or analyzing the correlation between the Earth's tilt and seasonal changes. This level of questioning is crucial as it helps students synthesize information from various sources and perspectives, enhancing their critical thinking skills. The progression from basic recall to higher-order thinking not only assesses students' knowledge but also prepares them to tackle complex environmental issues with a well-rounded understanding of geospheric dynamics.

We designed a set of 30 questions to assess students' understanding of geospheric phenomena at various cognitive levels, from basic recall to advanced analytical thinking. The structure of these questions actively engages students with the GeoSmart application, enabling them to explore geospheric concepts through interactive simulations and data analysis. The design of the questions is meticulous, aiming to assess not only factual knowledge but also the ability to apply, analyze, and evaluate complex geospheric processes such as tectonic plate movements, volcanic activity, and atmospheric interactions. The integration of the GeoSmart application in these assessments encourages students to bridge theoretical knowledge with real-world applications, thereby fostering a deeper and more practical understanding of geospheric phenomena.

Some key questions exemplify the effectiveness of this assessment approach. These questions require more than simple recall; they prompt students to interpret data, analyze environmental factors, and understand the interactions between various layers of Earth's systems. For instance, one question explores the interaction between the biosphere and atmosphere, challenging students to understand and explain the exchange of gases like oxygen and carbon dioxide. Other questions further push students to analyze tectonic boundaries, seasonal changes, and atmospheric dynamics, thereby deepening their understanding of the interconnectedness of geospheric processes. By incorporating these thought-provoking questions, the assessment not only evaluates students' knowledge but also enhances their ability to think critically about Earth's geospheric phenomena. **Table 5** provides an analysis of assessment questions designed to evaluate students' understanding of geospheric phenomena using the GeoSmart application.

The design of these questions builds upon each other, assisting students not only in learning but also in understanding and applying their knowledge of geospheric phenomena in various contexts. We craft them to challenge students at multiple cognitive levels, ensuring a thorough assessment of their understanding, and making them suitable for use in high-quality educational settings, including internationally accredited journals.

We assessed the effectiveness of the GeoSmart application in improving students' understanding of geospheric phenomena through pre- and post-application tests. **Table 6** provides a summary of the descriptive statistics, showing significant increases in mean scores after using the application. The t-test results in **Table 7**, which confirm the statistical significance of the observed improvements, further support these findings and highlight the application's impact on student learning outcomes.

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Table 5. Example analysis of GeoSmart-assisted assessment questions on geospheric phenomena.

Example questions and answer choices	Analysis
How does the biosphere interact with the atmosphere? a) Plants take in carbon dioxide and release oxygen. b) Animals consume nitrogen directly from the atmosphere. c) The atmosphere generates energy for all living beings. d) The biosphere sends water vapor into the atmosphere.	This question assesses students' understanding of the interaction between the biosphere and atmosphere, focusing on the essential exchange of gases, such as oxygen and carbon dioxide, that support life on Earth.
Given a map showing tectonic plate boundaries, which regions are most likely to experience earthquakes? a) Regions with varying boundaries. b) Regions along transform and convergent boundaries are identified. c) Areas situated at the intersection of tectonic plates. d) Regions near Earth's poles.	This question requires students to analyze tectonic plate boundaries and predict regions prone to earthquakes, reinforcing their understanding of how tectonic activity influences seismic events.
Analyze the correlation between the Earth's tilt and seasonal changes. Why do some regions experience more extreme seasons than others? a) This is due to the uneven distribution of sunlight throughout the year. b) Because of the varying distances from the sun, c) The influence of ocean currents. d) Because of volcanic activities.	This question tests students' ability to analyze how the Earth's tilt affects seasonal changes, helping them comprehend why different regions experience varying seasonal intensities.
Based on the GeoSmart application's data on atmospheric layers, how does the stratosphere differ from the troposphere in terms of temperature variation? a) The stratosphere cools with altitude, while the troposphere warms. b) The troposphere cools with altitude, while the stratosphere warms. c) Both layers cool uniformly with altitude. d) With altitude, both layers heat uniformly.	This question focuses on students' understanding of atmospheric layers and the differences in temperature variation between the troposphere and stratosphere, reinforcing their comprehension of atmospheric science.

Table 6. Descriptive statistics of students' understanding scores before and after using the GeoSmart application.

Trial	Number of Students	Mean Score Before	SD Before	Mean Score After	SD After	Mean Increase
Alpha	20	65.2	4.8	78.6	5.1	13.4
Beta	86	67.5	5.2	85.1	4.9	17.6

Table 6 presents the descriptive statistics of students' understanding scores before and after using the GeoSmart application. In the alpha test, the mean understanding score increased from 65.2 to 78.6, showing a mean increase of 13.4. The beta test showed similar results, with the mean score increasing from 67.5 to 85.1, reflecting a mean increase of 17.6. The standard deviation (SD) indicates that the variability in students' scores decreased after using the application, suggesting that students' understanding became more consistent.

Table 7. Inferential statistical test results (t-test) of students' understanding scores.

Trial	t-value	p-value	df	Interpretation
Alpha	8.25	< 0.001	19	Significant
Beta	12.45	< 0.001	85	Significant

Table 7 presents the t-test results showing that the increase in students' understanding scores before and after using the GeoSmart application is statistically significant ($p < 0.001$) in both the alpha and beta tests. The high t-value indicates that the difference in mean scores before and after using the application is highly significant. The primary findings of this study indicate that the GeoSmart application significantly enhances students' understanding of geospheric phenomena. The substantial increase in understanding scores can be attributed to the interactive features of the GeoSmart application, which provide a more immersive and participatory learning experience.

In the alpha test, the mean increase of 13.4 shows that the application effectively improves students' mastery of geospheric material in the short term compared to conventional learning methods. The beta test further supports these findings, with a mean increase of 17.6, suggesting that the GeoSmart application has greater potential when implemented on a larger scale. The t-test results reinforce these findings, with a significant p-value (< 0.001), indicating that the observed improvement is not due to chance but is genuinely due to the use of the GeoSmart application.

Further analysis also reveals that the GeoSmart application not only improves conceptual understanding but also enhances student engagement and motivation in learning geography. This aligns with interactive learning theories that emphasize the importance of active student involvement in the learning process. Students using this application reported feeling more interested and better able to grasp previously challenging material. This suggests that the GeoSmart application functions not only as a learning aid but also as a motivator for students' learning. Overall, these findings support the importance of integrating technology into education, particularly in the field of geography. The GeoSmart application has proven to be an effective tool for enhancing the quality of learning, which can be adopted more broadly in various educational contexts.

4.1.6. Distribution

The GeoSmart application, developed as an interactive learning medium, has a file size of 83.27 MB after being built into a *.apk format for installation on Android devices. Once the interactive learning media product was fully developed and passed through the testing phase, the next step was product distribution. Distribution was carried out by uploading the application to an online platform, specifically Google Drive, generating a download link: https://bit.ly/Download_GeosmartbyAprilia. This link was then shared with users via social media or can be downloaded using the barcode in **Figure 6** for the GeoSmart Application.

Figure 6. Barcode GeoSmart application.

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4.2. Discussion

The results of this study indicate a significant improvement in students' understanding of geospheric phenomena after using the GeoSmart application. These findings align with interactive learning theories that emphasize the importance of active student engagement in the learning process to enhance comprehension of complex concepts (Breines & Gallagher, 2023). The GeoSmart application, with its interactive features, allows students to engage more deeply with the learning material, directly contributing to their improved understanding. In the context of geography, geospheric phenomena are often difficult to grasp due to their abstract nature and the need for precise visualization. The use of interactive visual media in education can significantly enhance students' understanding, particularly in subjects requiring complex visual representation, such as geography (Stull *et al*., 2021).

Furthermore, some findings support the research that gamification and interactive elements in educational applications can increase student motivation and engagement (Dichev & Dicheva, 2017). The GeoSmart application, which incorporates interactive simulations and gamification, has proven effective in motivating students to engage more actively in their learning, thereby reinforcing their comprehension of the material. This is consistent with cognitive motivation theory, which posits that active engagement in the learning process can enhance retention and understanding (Deci & Ryan, 2000). Overall, these findings affirm that integrating interactive technology in geography education not only improves conceptual understanding but also boosts student motivation and engagement, both of which are crucial for effective learning.

Theoretically, this study strengthens the concept in social constructivist theory, which emphasizes the importance of social interaction and the use of tools in the learning process (Misra, 2020). The GeoSmart application functions as a learning tool that allows students to build their understanding through interaction with rich digital content. It also supports the view that technology-based learning is a means to create a dynamic and student-centered learning environment where students can explore and manipulate information independently (Breines & Gallagher, 2023).

In practical terms, these findings make a significant contribution to the application of educational technology in geography classes. The GeoSmart application enables teachers to present complex geography content more interactively and engagingly, making it easier for students to understand. This supports previous research findings that educational technology can facilitate more adaptive and personalized learning, allowing students to learn at their own pace and according to their learning style (Hover & Wise, 2022; Jong *et al.*, 2020). Furthermore, GeoSmart applications enable teachers to track student progress in real-time, delivering prompt and precise feedback that enhances student learning outcomes (Baidoo-Anu and Ennu Baidoo, 2024; Tsai *et al.*, 2020).

Another practical implication of this research is the potential for the wide adoption of the GeoSmart application in geography curricula across schools. This application can be an effective tool to overcome challenges in teaching complex and abstract geospheric concepts and to increase student engagement in learning (Markowitz *et al.*, 2018, Potkonjak *et al.*, 2016). It also highlights that investment in the development and implementation of interactive educational technology can yield significant results in terms of improving educational quality, especially in subjects that demand deep understanding, such as geography.

Despite the positive results of this study, several limitations should be acknowledged. First, the study was conducted on a limited scale, with a sample that included only students from three high schools in Tasikmalaya City. This limitation affects the generalizability of the study's

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findings to a broader population. To obtain more representative results, further research should be conducted with a larger and more diverse sample, including schools from various regions with different socioeconomic backgrounds.

Second, this study only measured the short-term improvement in students' understanding after using the GeoSmart application. The long-term impact of using this application on knowledge retention and the application of geospheric concepts in real-world contexts has not been thoroughly investigated. Longitudinal research is necessary to evaluate the effectiveness of the GeoSmart application over time and to understand how it can be effectively integrated into a sustainable geography curriculum.

Third, although this study demonstrates that the GeoSmart application improves students' understanding, other aspects of the learning experience, such as the development of critical thinking skills and problem-solving abilities, have not been evaluated. The development of higher-order cognitive skills is one of the primary goals of education (Peng *et al.*, 2024; Antonio & Prudente, 2024; Mitani, 2021). Therefore, future research should consider the impact of using this application on the development of these skills, as well as how the application can be used to enhance students' ability to analyze and solve complex problems.

5. CONCLUSION

This study confirms that the GeoSmart application significantly enhances students' understanding of geospheric phenomena through its interactive and immersive features. Statistical analysis shows a marked improvement in comprehension after using GeoSmart in both test phases. The application's simulations and quizzes make complex geospheric topics more accessible and engaging. By integrating GeoSmart into geography education, teachers can boost student motivation and create a more dynamic learning experience. Future research should explore the generalizability of these findings across diverse educational settings and assess the application's long-term impact on knowledge retention and cognitive skill development. GeoSmart has the potential to revolutionize geography education by deepening students' understanding and interest in complex concepts.

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