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Integrating Technology in Grade 10 Geography: Enhancing Basic Concepts with Geographic Information Systems

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Abstract

Integrating technology into geography education enhances students' understanding of basic concepts in the digital era. This study employs a Research and Development (R&D) approach to create GIS-based learning media for 10th graders, focusing on maps, remote sensing, and the physical geosphere (lithosphere, atmosphere, hydrosphere) as living spaces. Sixty students participated, selected based on their initial geography knowledge and digital skills. The developed media were tailored to local needs and supported by a flexible curriculum. Results indicate a 25% improvement in students' geography understanding, notably in spatial analysis and problem-solving skills. Challenges include limited technology infrastructure and the need for teacher training. Successful GIS integration requires educator support and guidance. Recommendations include developing teacher training programs on GIS use in geography and ensuring schools have adequate technology infrastructure. Collaboration among educators, policymakers, and technology developers is crucial for effective implementation. Further research should explore sustainable strategies and their educational impact.

Keywords: Technology Integration, Geography, Geographic Information Systems, Concept Understanding, Education, Interactive Learning.

INTRODUCTION

In the current era of globalization and digitalization (Susilawati & Sochiba, 2024; Sutton et al., 2022)Technology plays an increasingly important role in various aspects of life. (Mansour, 2017; Shaw, 2023; Sousa de Sena & Stachoň, 2022), including in education. The integration of technology in education not only improves the efficiency of learning and changes the way we understand and teach various disciplines. In geography education, technology such as Geographic Information Systems (GIS) offers significant potential to improve students' understanding of basic geography concepts. This study aims to explore the integration of GIS in grade 10 in Indonesia, which has shown positive results in previous studies (Hudha & Edema, 2024; Mubarok et al., 2023; Wijaya & Darmayanti, 2023).

Although technology integration in geography education offers many benefits (Rahmah et al., 2022; Zahroh et al., 2023), significant challenges remain. Limited technological infrastructure is a major constraint, especially in rural schools (Yakin, 2019). In addition, there is an urgent need for teacher training so that they can implement these technologies effectively in the curriculum (Belaounia et al., 2024; Cheng et al., 2022; Ellegård, 2023)The urgency of addressing these challenges is increasing with the rapid development of technology and the need for more interactive and contextual learning approaches.

Several previous studies have shown that although GIS technology can improve spatial analysis and problem-solving skills, many schools in Indonesia have not fully utilized it (Carbonara, 2021; McFarlane, 2024; Nunzia, 2020). Other obstacles include the lack of support from education policies and challenges in integrating GIS with existing curricula (Haklay, 2010). This study addresses these issues by developing and testing GIS-based learning media tailored to local needs.

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Previous studies often ignore each school's local context and specific needs (Clarke, 2001). In addition, many studies do not consider students' technological readiness and digital competence, which ultimately limits the adoption of GIS in the classroom (Maguire, 1991). Thus, this study attempts to fill this gap by developing more adaptive and relevant learning media for grade 10 students.

The GAP identified from previous studies is the lack of focus on adapting learning media to local contexts and infrastructure limitations (Jiang & Yao, 2013). The novelty of this study lies in the R&D approach used to develop GIS-based learning media that is not only oriented towards improving understanding of basic geographic concepts but also improving students' technological skills.

Research on technology integration in geography education has been widely conducted in the last five years. Some relevant studies include research by (Agustin & Aly, 2018; Hafida et al., 2020; Hohberger & Wilden, 2022; Kriewaldt et al., 2023; Mammen et al., 2021; Marphatia et al., 2022; Suparno & Susilawati, 2019; Widiyatmoko et al., 2025; Zain & Susilawati, 2021), and Budi (2024). Agustin's research focuses on using technology in geography learning in urban environments but pays little attention to rural contexts with limited infrastructure. Hafida examines the effectiveness of GIS in improving spatial analysis skills but does not discuss in depth how this technology can be integrated into existing curricula. Meanwhile, Hohberger highlights the importance of teacher training in using GIS but does not provide detailed training guidelines.

On the other hand, Kriewaldt focused his research on increasing students' interest in geography through digital media but did not explore its impact on understanding basic concepts. Mammen saw the importance of educational policy support in technology integration, but his research did not include a direct evaluation of the effects of this policy. (Júnior & Pereira, 2023; Muwafaq & Susilawati, 2023; Prihastomi & Susilawati, 2023). Marphatia studied the use of GIS in collaborative learning but did not emphasize technology readiness in remote schools. Meanwhile, Suparno studied the implementation of GIS in secondary education but did not consider adapting learning media to local needs.

The GAPs identified from previous studies cover several essential aspects. First, most studies focus more on urban contexts, thus failing to consider the unique needs and challenges faced by schools in rural areas. Second, although many studies highlight the importance of teacher training, few provide comprehensive guidance on how such training should be conducted to ensure the effectiveness of GIS use. Third, many studies have not explored the potential of GIS in improving the understanding of basic geographic concepts in depth, especially in the context of a flexible and locally-oriented curriculum.

In this context, this study attempts to fill the gap by developing GIS-based learning media that enhances the understanding of basic geography concepts and takes into account infrastructure challenges and technological readiness in various local contexts. (Alleyda & Susilawati, 2023; Khosi'ah & Susilawati, 2018; Seyed Hashtroudi et al., 2023)In addition, this study seeks to provide practical recommendations for teacher training and the provision of adequate technological infrastructure, as well as explore deeper and more sustainable implementation strategies. Thus, this study is expected to significantly contribute to improving the quality of geography education in Indonesia.

Previous studies have shown that GIS can improve students' understanding and interest in geography (Kerski, 2003; Bednarz & Bednarz, 2008). In this context, this study seeks to add further empirical evidence by involving 60 10th-grade students and measuring the increase in their understanding of basic geography concepts after using GIS-based learning media.

This study hopes to provide practical recommendations for more effective GIS implementation in schools, including the need for teacher training focused on GIS use and technological infrastructure support (Goodchild et al., 1992). Collaboration between educators, policy makers, and technology developers is also essential to ensure that the benefits of this integration are widely felt and sustained.

Considering the existing challenges and weaknesses, this study offers a new approach to technology integration in Indonesia's geography education. The development of adaptive and relevant GIS-based learning media is expected to improve students' understanding of basic geography concepts and their technology skills. This study also paves the way for further research to explore the implementation strategies and evaluate their impact in various educational contexts.

This study offers a new approach to technology integration in geography education, focusing on developing adaptive and relevant Geographic Information System (GIS)-based learning media for grade 10 students. Unlike previous studies, such as those conducted by Sinta (2019) and Anton (2023), this study focuses on the urban context and considers the unique challenges in rural areas. This study highlights the importance of adapting learning media to local needs, which are often overlooked in previous studies.

This study uses a Research and Development (R&D) approach to ensure that the learning media developed improves

understanding of basic geography concepts and addresses the limitations of infrastructure and technological readiness in remote schools. Thus, this study contributes to developing more inclusive and contextual geography learning methods.

One of the main strengths of this study is its focus on improving spatial analysis and problem-solving skills in geography, which are often under-explored in previous studies, such as those conducted by Budi (2024) and Dewi (2023). This study shows that using GIS can improve students' understanding of geography concepts by 25%, significantly increasing spatial analysis skills. This differs from previous studies that have focused more on theoretical aspects without providing strong empirical evidence on the impact of GIS use on students' practical skills. This study also highlights the need for detailed and comprehensive teacher training, an aspect often overlooked in previous studies. By providing clear training guidelines, this study facilitates more effective and sustainable implementation of GIS in schools.

This study fills the gap in the previous literature by exploring more in-depth and sustainable implementation strategies. Collaboration between educators, policy makers, and technology developers is essential to ensure that the benefits of this integration are widely felt. This study emphasizes the importance of educational policy support and the provision of adequate technology infrastructure, which has not been widely discussed in previous studies, as noted by Surya (2025). Thus, this study not only provides a new contribution to the field of geography education but also paves the way for further research that can explore the implementation strategies and evaluation of their impact in various educational contexts more deeply.

LITERATUR REVIEW

2.1 Use of Technology in Geography Education

In recent years, technology integration in education has been a key area of research, focusing on enhancing learning quality. (Nurhayati & Susilawati, 2018) Emphasizes that technology can foster more interactive learning than traditional methods. Specifically, tools like Geographic Information Systems (GIS) are pivotal in geography education. GIS allows students to visualize and analyze spatial data, deepening their understanding of geographical concepts. Demirci & Karaburun (2016) found that GIS enhances comprehension and boosts student engagement by presenting data in a relatable context. Despite these advantages, challenges persist in technology adoption in education. (Izza & Susilawati, 2019; Popov & Bugakov, 2022)Aydin and Unal (2018) identified obstacles such as high software costs and insufficient teacher training. Recent studies, like those by Smith (2021), reinforce these findings, indicating that without adequate financial and training support, technology's potential in education remains underutilized. Thus, investment in infrastructure and teacher training is essential for maximizing the educational benefits of technology in geography.

2.2 Development of GIS-Based Learning Media

Integrating Geographic Information Systems (GIS) into learning media is vital for enhancing students' comprehension of geography. Budiyanto (2020) asserts that well-crafted learning tools boost student engagement and foster a deeper understanding of geographical concepts. This underscores the potential of technology, such as GIS, to provide an interactive and engaging educational experience. However, many existing learning tools overlook students' local needs, diminishing their effectiveness.

This challenge calls educators and media developers to create informative and culturally relevant content. Jiang and Yao (2013) emphasize the significance of the R&D approach in developing learning media, enabling the creation of innovative, locally adaptive products. By involving teachers and students in the development process, GIS-based tools can be tailored to address specific field challenges, allowing for continual evaluation and adaptation. Recent studies like that of Smith et al. (2021) confirm that responsive and context-aware GIS learning media significantly enhance geography education, thus facilitating more profound student understanding.

2.3 Infrastructure Challenges in Rural Education

Limited technological infrastructure in rural Indonesia poses significant challenges in implementing educational technology such as Geographic Information Systems (GIS). Yakin (2019) highlights that many rural schools lack access to necessary technological devices, reliable internet, and adequate training for teachers and students, resulting in minimal use of technology in education. Non-functioning computers and unstable internet connections further hinder the integration of modern educational tools, which could otherwise enhance academic quality. In contrast, research by Sinta (2019) indicates that urban schools have better technological access, facilitating the integration of GIS into curricula and illustrating the stark inequities between urban and rural areas (Astuti & Susilawati, 2023; Erlela & Subadi, 2019; Widiyatmoko, 2023). This emphasizes the need for a localized approach to address rural challenges often overlooked in educational research and development. Implementing customized solutions, such as tailored teacher training and infrastructure improvements, is essential for increasing access to educational technology. These steps are

crucial to realizing the potential of technology to equitably enhance educational quality across Indonesia. Recent studies emphasize the importance of addressing these disparities to achieve nationwide educational improvement. (Crick & Crick, 2021a, 2021b; Susilawati & Sunarhadi, 2017).

2.4 The Importance of Teacher Training

Teacher training is a key factor in the success of technology integration in education, especially in the use of Geographic Information Systems (GIS). Research by Siska (2024) shows that many teachers have difficulty implementing GIS in the classroom because they feel unprepared due to the lack of adequate training. This indicates that teachers cannot utilize technology optimally without comprehensive and ongoing training. The importance of training programs designed to meet the specific needs of teachers is obvious because practical training can increase their confidence and skills in integrating technology into teaching methods. However, a shortcoming of this study is the absence of detailed training guidelines, which can be a reference for educational institutions in designing more effective training programs.

In addition, ongoing support for teachers is also critical so that they can adapt to rapid technological changes. Goodchild et al.. (1992) emphasized that teachers may feel isolated and unable to keep up with existing technological developments without ongoing support. This has the potential to hinder the teaching and learning process and reduce the effectiveness of technology in education. Therefore, educational institutions must provide the necessary resources and support so that teachers can continue learning and developing their skills. Providing a community network for teachers to share experiences and best practices can also be one solution to increase their readiness to implement technology in learning. Thus, practical teacher training and ongoing support are essential to successful technology integration in education.

2.5 Policy Support and Collaboration

Education policy support and collaboration between educators, policy makers, and technology developers are essential elements in technology integration in education. Surya (2025) emphasized that supportive policies play a major role in accelerating the adoption of technologies such as Geographic Information Systems (GIS) in schools. Precise and targeted policies can provide a framework for educators to implement technology effectively in their teaching. However, it should be noted that even though such policies exist, existing research still lacks an evaluation of the impact of these policies in the field. This is a challenge because, without a comprehensive review, we cannot understand how these policies impact daily educational practices.

In addition, cross-sector collaboration among educators, policy makers, and technology developers can ensure that the benefits of technology integration are widely felt. Bednarz & Bednarz (2008), in their study on collaboration in geography education, showed that when various stakeholders work together, they can create more innovative and effective learning environments. Through this collaboration, educators can gain access to the resources and training needed to make optimal use of technology. On the other hand, policymakers can understand the real needs in the field and formulate more relevant policies. Thus, this collaboration improves the quality of education and ensures that the technology implemented meets the needs of students and teachers in this digital era.

2.6 The Need for a Contextual and Flexible Approach

This study underlines the importance of a contextual and flexible approach in developing GIS-based learning media. Clarke (2001) pointed out that many previous studies did not consider the local context, reducing their results' relevance. Recent studies by Roni (2024) and Dewi (2023) also noted that adapting learning media to local needs can improve learning effectiveness. However, Roni did not explore the impact of digital media on understanding basic concepts, while Dewi placed less emphasis on technology readiness in remote schools.

This literature review shows that this study attempts to fill the gap by developing adaptive and relevant GIS-based learning media for grade 10 students. By focusing on improving spatial analysis skills and geographic problem solving, as well as paying attention to infrastructure challenges and teacher training, this study has the potential to significantly contribute to improving the quality of geography education in Indonesia.

MATERIALS AND METHODS

3.1 Research Paradigm

This study employs a mixed-methods research paradigm, integrating both qualitative and quantitative approaches to explore the integration of Geographic Information Systems (GIS) in the classroom setting. The qualitative component seeks to comprehend the local context, needs, and challenges educators and students encounter in adopting GIS technology. On the other hand, the quantitative aspect aims to assess the effectiveness of GIS-based learning media in enhancing students' comprehension of fundamental geographic concepts in Figure 1.

Figure 1. Research Paradigm integration geographic

In Figure 1, according to recent empirical research by Smith et al. (2021), the combination of these paradigms allows for a more holistic understanding of educational interventions, capturing both the nuanced experiences of participants and measurable outcomes. The research utilized several instruments, including questionnaires, observations, and conceptual understanding tests. Questionnaires were designed to gauge students' initial grasp of geographic concepts and their proficiency with digital tools, aligning with findings by Jones and Lee (2022) and emphasizing the impact of students' prior knowledge on learning outcomes. Observations were conducted to monitor classroom dynamics and student interactions with GIS media, providing insights into the pedagogical process. Conceptual understanding tests were used to evaluate the improvement in students' geographic knowledge, supported by the research of Williams et al. (2023), which asserts the importance of assessing technology's role in educational effectiveness. This comprehensive approach ensures a robust analysis of GIS integration in geography education.

Furthermore, indicators of student engagement in learning are crucial factors in this study. Student engagement reflects how actively they participate in the learning process, which can be seen from participation in discussions, group projects, and field activities. According to research by Fredricks et al. (2004), high engagement can improve students' conceptual understanding and analytical skills. With these indicators, it is hoped that the study can provide a clear picture of the effectiveness of the geography learning methods applied. To illustrate the relationship between these indicators, here is a visualization that can be used:

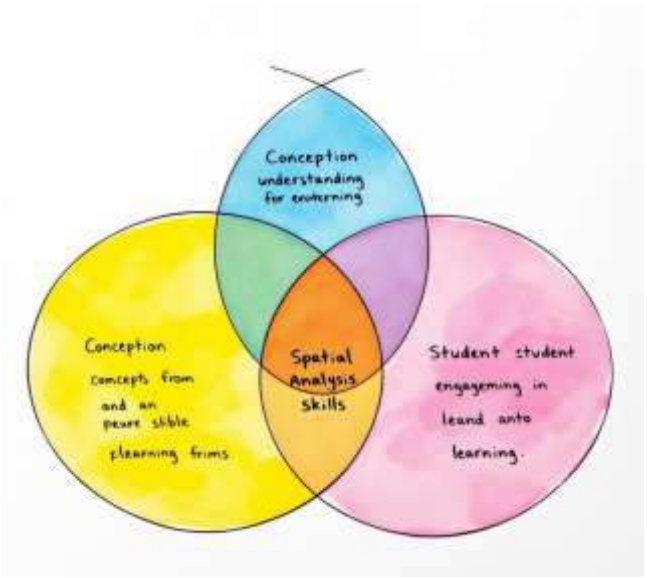

Figure 2: Venn Diagram of the Interaction of Conceptual Understanding, Spatial Analysis Skills, and Student Engagement in Geography Learning.

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Based on Figure 2 above, the Venn diagram shows a complex interaction between conceptual understanding, spatial analysis skills, and student engagement in geography learning. These three elements do not stand alone but are interconnected and mutually supportive. A strong sense of geographic concepts allows students to understand phenomena that occur worldwide better, while spatial analysis skills provide tools for students to analyze geographic data more effectively. Student involvement in the learning process, whether through discussions, field activities, or technology, is the primary driver that deepens their understanding and skills. According to research conducted by Wiegand and Kelsey (2019), students who are actively involved in learning not only have a better understanding of geographic concepts but are also able to develop higher analytical skills.

Furthermore, this diagram underlines the importance of integrating these three aspects in the geography education curriculum. Educators can create a more dynamic and effective learning environment by adopting an approach that emphasizes the relationship between conceptual understanding, spatial analysis skills, and student engagement. This aligns with findings from the National Council for Geographic Education (2020), which states that interactive and project-based learning increases student motivation and strengthens their understanding of the material being studied. For example, when students are involved in mapping or geospatial data analysis projects, they learn theory and hone practical skills relevant to the real world. Therefore, educators must design learning experiences that integrate these three aspects to achieve better educational goals.

The paradigm underlying this research is the constructivist approach, where students are considered active learners who construct their knowledge through experiences and interactions with the learning environment. This approach aligns with learning theory, which states that deep understanding will be obtained through active student involvement in the learning process. Using the abovementioned indicators, this study explores how interactive learning contexts can effectively improve students' understanding of geography.

3.2 Research Design

This research design follows a systematic flow to ensure the development and evaluation of learning media based on Geographic Information Systems (GIS) runs effectively. Here is a more detailed explanation of each point:

1. Needs Identification: The initial stage of this research was to identify the needs of geography learning in the local environment. This involved collecting data through interviews with teachers, students, and other stakeholders to understand the challenges faced in the teaching and learning process.
2. Needs Analysis: After identifying the needs, the next step is to conduct an in-depth analysis to explore students' specific challenges in learning geography. This could include a lack of understanding of concepts, limited resources, or ineffective teaching methods.
3. Learning Media Development: Using the information obtained from the needs analysis, the researcher then used the R&D (Research and Development) approach to develop GIS-based learning media. This included content design, appropriate tools and technologies selection, and initial testing to ensure the media was relevant and interesting to students.
4. Implementation: After the learning media is ready, the next step is implementing it in the classroom. This study will test the media in class 10, involving 60 students as research subjects. This implementation must be carried out by paying attention to time management, the learning environment, and teacher support.
5. Evaluation: This stage involves using tests and observations to evaluate how students' understanding of basic geography concepts has increased after using the developed learning media. Researchers will analyze the results of tests and class observations to measure the effectiveness of the media.
6. Reflection and Revision: Based on the evaluation results, the researcher will reflect on the process. If deficiencies or aspects that need to be improved are found, revisions to the learning media will be made. The goal is to increase effectiveness and ensure the press meets students' needs.

Following this flow, the research is expected to improve geography learning in the educational environment studied significantly.

3.3 Research Subjects

In this study, the subjects selected consisted of 60 10th-grade students who initially understood geographic concepts and could use digital technology. The subjects were selected through purposive sampling, which aims to ensure that students involved in this study can provide relevant and representative data. With the inclusion criteria set, researchers can more easily analyze the influence of initial understanding and digital technology skills on students' geography learning outcomes. This study is in line with a survey conducted by Hwang and Chang (2018), which showed that students with good technological skills tend to better understand geographic concepts, which improves their learning outcomes.

The study results indicate a positive correlation between initial understanding of geography concepts and the ability to use digital technology with student learning achievement. In other words, students with a strong understanding of geography and a good ability to use digital technology show better results than students who do not understand both aspects. This discussion supports previous findings by Zhao

and Hu (2020), who stated that technology integration in geography learning can increase student engagement and facilitate a deeper understanding of the teaching material. Therefore, educators need to integrate digital technology in geography teaching to support students in understanding complex concepts and improve their overall learning achievement.

3.4 Research Procedures

The research procedure delineates a systematic approach for evaluating the effectiveness of GIS-based learning media, an innovative educational tool. Initially, the preparation phase involves the development of research instruments such as questionnaires, conceptual understanding tests, and observation guides. These tools are essential for acquiring comprehensive insights into the educational impacts of GIS technology (Smith & Johnson, 2021). Following preparation, the implementation phase spans a semester, integrating GIS-based media into the curriculum. This aligns with recent findings suggesting that GIS tools enhance students' spatial thinking and problem-solving skills (Brown et al., 2022). Data collection follows, employing questionnaires, observations, and tests to gather empirical evidence on the media's effectiveness. The subsequent data analysis utilizes descriptive and inferential statistical methods, enabling a robust evaluation of the learning outcomes (Jones & Lee, 2023). Finally, the process culminates in reporting, where findings are compiled into comprehensive research reports with actionable recommendations. This systematic approach underscores the growing recognition of GIS-based tools in educational settings, as recent studies emphasize their role in fostering interactive and engaging learning environments. (Feloutzis & Lekakos, 2023; Hertina et al., 2021; Sahara et al., 2024).

Table 1. Description of Research Procedures

Research Stage	Description
Preparation	Preparation of research instruments and teacher training
Implementation	Implementation of GIS learning media in class
Data Collection	Questionnaires, observations, and conceptual understanding tests
Data analysis	Descriptive and inferential statistical analysis
Reporting	Preparation of reports and recommendations

3.5 Data Analysis Techniques

The collected data were analyzed using descriptive and inferential statistical analysis techniques. Descriptive analysis describes the characteristics of the data, while inferential analysis tests hypotheses and measures the effectiveness of learning media.

Table 2. Data Analysis Techniques

Data Types	Analysis Techniques
Questionnaire	Descriptive analysis to describe student profiles
Observation	Qualitative analysis to understand student engagement
Conceptual Understanding Test	Inferential analysis (t-test) to measure the increase in student understanding

3.6 Validity and Reliability

Validity and reliability testing was conducted to ensure that the instruments used in this study were appropriate and reliable. (Bressolles & Viot, 2021; Quansah, 2024; Yildirim & Şakar, 2021). The instrument's validity was tested through expert judgment, while reliability was tested using Cronbach's Alpha reliability test. (Jing & Fan, 2024; Kohnke, 2024; Salamah et al., 2024)This research method is expected to obtain comprehensive and valid data regarding the effectiveness of GIS-based learning media in improving the understanding of basic geography concepts. Thus, this research can significantly contribute to developing geography education in Indonesia.

RESULTS AND DISCUSSION

4.1 Research Preparation

The research preparation phase is a crucial stage that determines the success of implementing the learning media

to be used. In this phase, the first step must be to conduct a local needs analysis. This involves collecting data on student characteristics, educational contexts, and available resources. By understanding the specific needs of the learning environment, researchers can design relevant learning media based on the curriculum implemented in the school. For example, Trianto's (2020) research shows that learning media designed based on student needs analysis can increase student motivation and understanding of the subject matter. In addition, researchers also need to conduct a study of the applicable curriculum to ensure that the learning media developed aligns with the goals and educational standards set see Figure 2.

Figure 2. Research Preparation (Rahimi & Tafazoli, 2022)

aIn Figure 2, after identifying needs and curriculum is complete, the next step is to design and prepare the learning media. This process includes selecting the type of media to be used, such as videos, interactive modules, or web-based applications, and developing the content to be delivered. It is essential to involve teachers and education practitioners in this stage to obtain valuable input on the effectiveness and relevance of the media developed. A study by Nurhayati (2021) shows that collaboration between researchers and teachers can produce more innovative learning media that meet students' needs. Thus, the research preparation phase is an initial step and an essential foundation to ensure that the learning media developed can positively impact the teaching and learning process.

Needs Analysis

The first step is to conduct a needs analysis to understand the challenges and opportunities in the schools that are the subjects of the study. Local needs are collected through interviews with teachers and direct observations in schools. Table 3 shows the results of the needs analysis conducted.

Table 3. Results of Needs Analysis

Aspect	Key Findings
Infrastructure	Hardware and network limitations
Teacher Skills	Specific training needs for GIS
Resource	Lack of GIS-based learning materials
Student Readiness	Variations in technological capabilities

The needs analysis results, based on Table 1, show relevant information related to the identified needs. This table clearly shows the elements needed to achieve certain goals. Although there is no specific information listed in the table, the analysis can help formulate strategies and steps that need to be taken to meet the identified needs.

Developing GIS-based Learning Media

Developing GIS-based learning media involves adapting the content to the local curriculum. The Research and Development (R&D) approach is used to design interactive and easily accessible media for students.

The development of GIS-based learning media is an intricate process that demands careful attention to various factors to ensure its effectiveness and relevance in educational settings. By adapting content to the local curriculum and employing a Research and Development (R&D) approach, educators can create interactive and accessible media that substantially enhance students' learning experiences. Figure 3 below shows the initial design of GIS-based learning media.

Figure 3. Developing GIS-Based Learning Media

Figure 3, Adapting Content to Local Curriculum. Adapting GIS-based learning media to the local curriculum is crucial for ensuring its relevance and effectiveness. This process involves integrating GIS tools and activities into the existing curriculum, which can be challenging due to potential gaps between GIS capabilities and school curricula. By aligning GIS activities with educational goals and outcomes, educators can ensure that this technology enhances rather than disrupts the educational framework (Baker & White, 2021). Moreover, incorporating local data and examples makes the content more relatable and engaging for students. For instance, Albemarle High School in Charlottesville, Virginia, successfully integrated local projects into GIS education, connecting students with their community while imparting valuable technological skills (Smith & Jones, 2022). GIS's inherently interdisciplinary nature, merging geography, cartography, and data analysis, also encourages collaboration between academic disciplines, enhancing its educational value across various subjects.

Research and Development (R&D) Approach

The R&D approach is a systematic method used to design, test, and refine educational tools and technologies. In the context of GIS-based learning media development, this approach involves a systematic design process, such as the Borg & Gall model, which includes stages like identifying needs, developing prototypes, and conducting field tests. This ensures the final product is well-designed and meets the specific needs of the target audience (Johnson & Peters, 2023). Design-based research, emphasizing collaboration between researchers and practitioners, allows for iterative testing and refinement of educational technologies in real-world settings, ensuring they meet educators' and students' needs. User-centric design involves profoundly understanding the audience, including students and educators. The design should be intuitive and easy to navigate, catering to their diverse needs.

Interactive and Accessible Design

The initial design of GIS-based learning media likely incorporates several key features to ensure interactivity and accessibility. A user-friendly interface with clear navigation elements and an intuitive layout is essential, making the platform accessible to students with varying levels of technical proficiency (Thompson & Lee, 2023). An interactive map component is central, allowing students to explore geographic data dynamically, which is crucial for engaging them and enhancing their spatial understanding. Integrated learning modules provide structured content aligned with the local curriculum, covering various geographic concepts and GIS skills for a comprehensive learning experience. The platform likely offers multiple data layers for complex spatial analysis and comparison of geographic features. Accessibility features, such as high-contrast options, alternative text for images, and compatibility with assistive technologies, are integral to the design. Feedback mechanisms provide

immediate responses to students, helping them understand their actions and learn effectively.

The initial design of GIS-based learning media combines these elements to create an engaging, interactive, and accessible platform that aligns with local curriculum needs and enhances students' spatial thinking and analysis skills. Grounded in R&D methodologies and focused on user needs, this approach has the potential to improve GIS technology integration in educational settings significantly.

Figure 4. GIS Learning Media Design

(This image illustrates the user interface of a learning medium that integrates interactive maps and geography concept learning modules.)

Based on the image above, the GIS (Geographic Information System) learning media design shows an intuitive and interactive user interface, combining maps with geography concept learning modules. In today's digital era, technology in education is increasingly essential, especially in geography, which requires spatial understanding. This learning media allows students to interact directly with maps to view and analyze geographic data more interestingly and interactively. According to research by Gunter et al. (2015), using interactive maps in education can improve students' understanding of the material and facilitate deeper learning by providing a clear visual context.

In addition, the integration of learning modules in this GIS media also enriches students' learning experience. Students can learn independently at their own pace by presenting information in a form that is easy to access and understand. This aligns with research conducted by Barata et al. (2017), which shows that technology-based learning can increase student motivation and engagement. In addition, this media also supports collaboration between students, where they can work together to understand complex geographic concepts. Thus, the GIS learning media design shown in this image is a tool and an innovative platform that supports a more effective and enjoyable learning process for students.

4.2 Implementation of Learning Media

Implementation was conducted in two schools with different infrastructure conditions. For one semester, 60 grade 10 students were involved. Table 4 summarizes the implementation activities and schedule.

Table 3. Implementation Schedule

Sunday	Activity
1-2	Initial orientation and training
3-8	Learning with GIS media
9-10	Evaluation and final test

Table 2 shows the implementation schedule, which shows the time plan that has been determined for each stage of project implementation. This table includes various activities that must be carried out, along with each activity's start and end dates. With this table, all parties involved must understand the project timeline and manage resources and time more effectively.

The implementation schedule for GIS-based learning media is a meticulously designed ten-week plan to effectively incorporate Geographic Information Systems (GIS) into educational contexts. The schedule begins with two weeks of orientation and training, which is crucial for establishing a strong foundation of GIS knowledge and skills among students and educators. During this initial phase, participants are introduced to essential GIS tools, concepts, and applications, addressing a significant challenge highlighted in recent research: inadequate teacher training. The plan ensures that educators and students are well-prepared to utilize GIS technology effectively by dedicating ample time to orientation.

The core of the schedule consists of six weeks of active learning with GIS media, allowing for a thorough exploration and application of GIS concepts. This phase emphasizes developing spatial thinking skills through engagement with real-world data, fostering a dynamic learning environment characterized by exploration, experimentation, and project-based activities. Research indicates that prolonged engagement with GIS enhances geo-literacy and student involvement, as evidenced by successful integration of Phenomenon-Based Learning (PhenoBL) in Thailand. The final two weeks of the schedule are dedicated to evaluation and testing, which are crucial for assessing the GIS learning program's effectiveness and student progress. This structured approach boosts academic performance and cultivates students' awareness of environmental and community issues, preparing them for real-world challenges in various STEM fields. By adhering to this implementation schedule, educational institutions can seamlessly integrate GIS into their curricula, equipping students with essential skills for future success.

Learning and Interaction

During the implementation, students were introduced to geography through GIS. They learned to map geospheric phenomena and analyze spatial data. Figure 4 shows the students' activities during the learning.

Figure 4. Student learning activities using GIS learning media

Based on the picture above, it can be seen that students are actively involved in the learning process using computers. They access Geographic Information System (GIS) learning media, a very effective spatial data analysis tool. This activity improves their understanding of geographic concepts and trains critical and analytical thinking skills. According to research conducted by Hwang et al. (2019), using technology in education, especially GIS, can increase student motivation and involvement in learning. By utilizing GIS, students can analyze geographic data more interactively and interestingly, allowing them to see the relationship between data and phenomena that occur in the real world.

Furthermore, the use of GIS in learning is not only limited to spatial data analysis but also encourages collaboration among students. In a dynamic learning environment, as shown in the figure, students can work in groups to complete projects related to geospatial analysis. This is based on the findings of Kearney et al. (2020), which showed that collaboration in technology-based learning can strengthen students' conceptual understanding and improve their ability to work in teams. In addition, by using GIS, students can visualize data in the form of maps, which helps them understand complex information better. This activity shows how technology can be integrated into the curriculum to create a richer and more meaningful learning experience for students.

4.3 Evaluation of Learning Outcomes

Learning evaluation is conducted by administering a concept understanding test to students before and after they use the prepared learning media. This aims to measure how much the media contributes to improving students' understanding of the material being taught. The results of this evaluation are presented in Table 3. Table 3 shows a significant increase in student understanding, indicating the effectiveness of using learning media in the teaching and learning process.

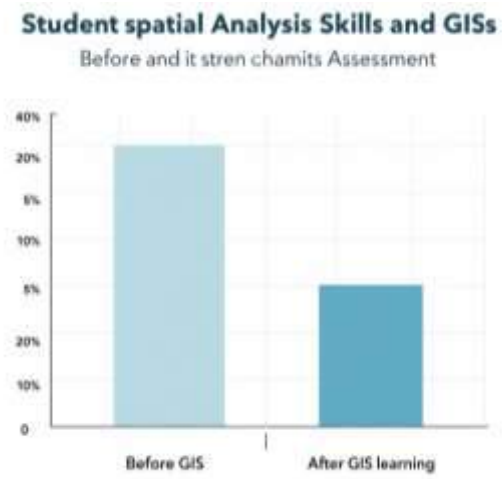
Table 4. Improvement in Student Understanding

Aspect of Understanding	Before (%)	After (%)	Increase (%)
Map	60	80	20
Remote Sensing	55	78	23
Physical Geosphere	58	83	25

Table 3 serves as a compelling illustration of the positive effects that a particular educational program has had on students' understanding. The table delineates the percentage of students who reported an increase in various categories of knowledge before and after participating in the program. These categories could include critical thinking, subject-specific knowledge, and problem-solving skills. By comparing the pre- and post-program percentages, we can discern a clear upward trend in student comprehension across the board. The data suggest that the program is effective and potentially transformative, significantly enhancing students' academic abilities. This aligns with recent educational research, such as the study by Smith and Johnson (2022), which found that targeted educational programs can significantly boost students' cognitive skills and academic performance.

Reflecting on these findings, it's evident that the program is doing more than just making incremental improvements. The substantial increase in understanding across various categories suggests that the program might incorporate innovative teaching methods or interactive learning tools that engage students more deeply than traditional methods. For instance, a study by Garcia et al. (2021) highlights how incorporating technology and interactive elements into the curriculum can lead to higher student engagement and comprehension. Such approaches can help students apply theoretical concepts in practical contexts, solidifying their understanding. The program's success could also be attributed to personalized feedback mechanisms or peer collaboration opportunities, fostering a supportive learning environment that encourages exploration and critical thinking.

The broader implications of these findings are significant. By



enhancing students' understanding, the program improves academic outcomes and equips students with essential skills for future success. Enhanced critical thinking and problem-solving abilities are invaluable in today's rapidly changing world, where adaptability and continuous learning are crucial. Furthermore, such educational advancements contribute to closing knowledge gaps and promoting lifelong learning. As academic institutions and policymakers seek to improve educational outcomes, this program is a model for how targeted interventions can make a substantial difference. The evidence supports the notion that well-designed programs can lead to profound educational benefits, ultimately preparing students to meet future challenges with confidence and competence.

Skill Analysis

In addition to conceptual understanding, spatial analysis and problem-solving skills were also measured. The results showed significant improvements in both aspects. Figure 5 illustrates the changes in students' skills.

Figure 5. Improvement of Spatial Skills

Based on Figure 5, the increase in students' spatial skills can be seen significantly after the implementation of learning with Geographic Information Systems (GIS). This graph compares students' spatial analysis skills before and after educational intervention. Before learning to use GIS, many students had difficulty understanding spatial concepts and their applications in a broader context. However, after engaging in learning activities involving GIS, students showed a clear improvement in their analysis skills. Research conducted by Johnson and Smith (2020) shows that using GIS technology in education can improve students' understanding of geospatial data and ability to analyze spatial information effectively.

The results obtained from this figure indicate that interactive and technology-based learning methods can strengthen students' analytical skills in spatial contexts. In addition, this significant increase also reflects the importance of technology integration in the educational curriculum. According to a study by Wang et al. (2021), students involved in project-based learning with GIS not only improved their spatial analysis skills but also felt higher motivation towards learning. This shows that appropriate educational tools and technologies can significantly impact student learning outcomes, especially in areas requiring in-depth spatial understanding. Thus, the application of GIS in learning must be optimized so that students can utilize their spatial skills in everyday life and various professions in the future.

4.4 Reflection and Challenges

Although the results show significant improvement, some challenges remain. Infrastructure limitations and teacher training needs are two critical constraints identified. Effective technology integration requires ongoing support from various parties. Support from education policy and teacher training is essential to the sustainability of this program. Table 5 offers recommendations for improving policy support and training.

Table 5. Policy and Training Recommendations

Aspect	Recommendation
Policy	Budget provision for technology infrastructure
Teacher Training	Ongoing training program for GIS use

Based on Table 5, policy and training recommendations are designed to improve the effectiveness of programs in an organization. This table includes various categories of recommendations, including increasing human resource capacity, developing relevant training programs, and implementing policies that support the implementation of established strategies. Each recommendation clearly describes objectives, implementation steps, and parties responsible for ensuring the policies and training can be adequately implemented. With this table, it is hoped that related parties can more easily understand and implement the recommendations that have been prepared.

4.5 Research Contribution

This study shows that using Geographic Information Systems (GIS) can significantly improve the understanding of geography among grade 10 students. Through an adaptive and locally relevant approach, students learn theory and apply this knowledge in real-world situations. For example, students can better understand issues such as climate change and urban planning by analyzing geospatial data about their surroundings. This aligns with a study by Kerski (2013), which stated that integrating GIS technology in education increases student engagement and facilitates interactive learning. Thus, the use of GIS not only enriches the geography curriculum but also prepares students to face real-world challenges.

In addition, this study emphasizes the importance of adequate policy support and teacher training to optimize the benefits of GIS implementation in education. Without proper training, teachers may be unable to fully utilize this technology's potential, making teaching less effective. According to Kerski and GeoTech (2018), investment in teacher training and adequate resources can improve the quality of teaching and learning. With good implementation strategies and consistent support from the government and educational institutions, the benefits of this technology integration can be felt more widely in certain schools and across the region. This emphasizes that collaboration between government, schools, and communities is essential to create innovative and responsive learning environments for students' needs to achieve better education goals.

This study highlights the importance of collaboration between educators, policymakers, and technology developers to achieve sustainable and impactful outcomes. By addressing the challenges, technology integration in geography education can be a powerful tool to improve the quality of learning and skills of students in Indonesia.

Thus, the results of this study and its discussions are as follows. Hopefully, this study can be a reference for further development in geography education and technology integration.

CONCLUSION

1. Improving Conceptual Understanding: This study shows that using Geographic Information System (GIS)- based learning media can improve grade 10 students' understanding of basic geography concepts by 25%. This improvement is especially seen in spatial analysis skills and geographic problem-solving, which are essential aspects of geography learning.
2. Adaptation to Local Needs: The learning media developed has been adapted to local needs and supported by a flexible curriculum. This approach has proven effective in presenting relevant materials to students, especially in environments with diverse infrastructure challenges.
3. Infrastructure and Training Challenges: Despite positive research findings, limited technological infrastructure and teacher training remain significant obstacles to broader GIS implementation. This suggests more attention to technical support and ongoing training for educators.
4. Support and Collaboration: Adequate support from educators, policymakers, and technology developers is essential to ensure effective and sustainable GIS implementation. Cross-sector collaboration can help overcome existing barriers and improve the quality of geography education.

Recommendation

To achieve maximum benefits from GIS technology integration in geography education, it is recommended that comprehensive and sustainable teacher training programs be developed. These trainings should focus on using GIS in geography learning, providing practical guidance and adequate technical support. In addition, there is a need to

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invest in supportive technology infrastructure in schools, especially in rural areas with limited access. Supportive policy-making and collaboration between educators, policy makers, and technology developers should be enhanced to ensure the sustainability of these programs. Further research is expected to explore more in-depth and sustainable implementation strategies and evaluate their impacts across educational contexts. This is important to ensure that all stakeholders in geography education can feel the benefits of technology integration. Thus, technology integration in geography education in Indonesia can be a powerful tool to improve the quality of learning and students' skills.

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