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RESEARCH ARTICLE

Constraints in Geographic Information Systems Learning Across Senior High Schools in Metro City

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ABSTRACT

This study addresses challenges in the implementation of Geographic Information System (GIS) learning in senior high school, particularly in supporting students' spatial thinking skills. The purpose of this research is to identify the main obstacles faced by teachers and students in GIS-based geography learning and to examine their implications for instructional practice. This study employed a qualitative descriptive approach, involving geography teachers and students as participants. Data were collected through classroom observations, interviews, and documentation, and then analyzed using data reduction, data display, and conclusion drawing techniques. The findings reveal that GIS learning has not been implemented optimally due to several key constraints, including limited teacher competence in operating GIS software, lack of adequate training, insufficient technological facilities, and low student engagement in practical activities. As a result, GIS is often taught theoretically rather than through hands-on practice, which limits the development of students' spatial thinking abilities. These findings imply that improving GIS learning requires systematic efforts, such as enhancing teacher professional development, providing adequate infrastructure, and integrating more practice-based learning strategies. Strengthening these aspects is essential to ensure that GIS can function effectively as a tool to support meaningful geography learning and to improve students' spatial competencies.

Keywords: GIS learning; teacher competence; student engagement; geography education; cross-site analysis

1. INTRODUCTION

The Geography learning at the senior high school level has a significant role in helping students understand environmental phenomena and spatial relationships. In today's educational context, geography is no longer limited to learning about maps and locations, but also involves understanding the interaction between humans and their environment, supported by the use of technology in analyzing geospatial data. One of the key materials that reflects this development is Geographic Information Systems (GIS). Through GIS, students are able not only to access spatial data but also to process and present it in a more meaningful way. Considering the increasing demand for GIS skills in various sectorsuch as urban planning, natural resource management, and disaster mitigation, mastering this subject becomes increasingly important for students (Aliman et al., 2020).

Nevertheless, the implementation of GIS learning in schools often encounters several obstacles. These challenges arise from both internal and external factors. Internally, many teachers still have limited understanding of GIS technology and face difficulties in integrating it into classroom instruction. A lack of experience in using GIS software also affects how the material is delivered. Externally, limitations in facilities and learning resources further complicate the situation. In fact, GIS has strong potential to support students in understanding spatial aspects of geospheric phenomena and analyzing human– environment interactions. It also aligns with the demands of 21st-century learning, as it promotes critical thinking and problem-solving skills based on spatial data. Research by Yulianto and Widyatmoko (2023) indicates that GIS-based learning can improve students' engagement and support more interactive teaching practices.

From a conceptual perspective, GIS is defined as a computer-based system used to collect, manage, analyze, and display spatially referenced data. It consists of several interconnected components, including spatial data, hardware, software, and human resources (Darwis et al., 2020). One of its main strengths lies in its ability to visualize geographic information in the form of digital maps and perform spatial analyses such as overlay, buffering, and modeling. However, these characteristics also make GIS relatively complex, as it requires both technical competence and analytical skills.

In the context of classroom learning, especially at the senior high school level, GIS is often perceived as a difficult topic. Students are expected not only to understand theoretical concepts but also to operate GIS software such as QGIS or ArcGIS. This situation requires appropriate learning strategies that emphasize hands-on activities and real-world applications. According to Dahrullah and Mariono (2025), active and contextual learning approaches are necessary to help students better understand and apply GIS concepts.

Initial findings from a preliminary survey conducted among geography teachers in Metro City provide further insight into this issue. The data show that although 61.9% of teachers consider GIS learning to be fairly well implemented, it is still not optimal, while 38.1% report that it remains very limited. In terms of infrastructure, most schools already have computer laboratories (80%), but only a small proportion (26.7%) have access to GIS software. Regarding teacher competence, although 66.7% of teachers have participated in GIS training, the implementation of practical GIS activities in classrooms is still infrequent. Many teachers only conduct practice occasionally, and some rarely or never apply it. This indicates that GIS learning is still largely theoretical and has not fully provided students with practical experience.

A number of previous studies have discussed GIS learning in schools. Nuriyanto et al. (2022) found that students tend to struggle with basic GIS concepts, particularly when applying them in practical contexts. Meanwhile, Yulianto and Widyatmoko (2023) highlighted the importance of adequate facilities and resources in supporting GIS learning. However, these studies generally focus on specific aspects and do not fully examine the relationship between teaching methods, student characteristics, and supporting infrastructure. In addition, many studies rely mainly on quantitative data and do not explore the experiences of teachers and students in depth. As stated by Lafia et al. (2021), a more comprehensive approach is needed to better understand the challenges in GIS education.

However, previous studies have primarily focused on individual aspects of GIS learning without sufficiently examining how these factors interact within actual classroom practice. This indicates a gap in understanding the complexity of GIS implementation in real school contexts. Based on this gap, the main problem addressed in this study is the limited integration between conceptual understanding and practical implementation of GIS in geography learning, which results in predominantly theoretical instruction. The novelty of this study lies in its effort to analyze GIS learning challenges from an integrated perspective by considering the interaction between teacher competence, student engagement, and infrastructural support across different school settings. This study aims to identify and analyze the challenges in the implementation of GIS learning at senior high schools in Metro City by examining constraints related to teachers, students, and institutional factors.

2. LITERATURE REVIEW

2.1 Geography Learning in Senior High Schools

Geography learning in senior high schools aims to develop students' understanding of spatial phenomena and the interaction between humans and the environment. It does not only focus on maps and locations, but also on how geographic conditions influence human activities and environmental processes (Bawamenewi & Yenny, 2025). Through this subject, students are expected to build spatial awareness and interpret geographic information in a more meaningful way.

In line with this, geography learning also encourages critical thinking, especially in addressing issues such as environmental change, disasters, and spatial planning. These competencies are relevant to the Merdeka Curriculum, which emphasizes critical reasoning, environmental awareness, and global perspective (Sobirin et al., 2024). The scope of geography learning itself includes physical and social aspects that are studied in an integrated manner using spatial, regional, and ecological approaches (Dahrullah & Mariono, 2025; Rahail, 2025; Jaka et al., 2025).

2.2 Geographic Information Systems (GIS) in Education

Geographic Information Systems (GIS) are computer-based systems used to process and analyze spatial data. GIS integrates map-based data with descriptive information, allowing users to visualize and analyze geographic phenomena more effectively (Darwis et al., 2020). Its main components include spatial data, hardware, software, and human resources, which work together to support geospatial analysis (Silvany & Supratikta, 2024).

In education, GIS plays an important role in making geography learning more interactive and applicable. Students can directly engage with spatial data through mapping and analysis activities, which helps improve their spatial thinking and problem-solving skills. The use of GIS also supports student- centered learning, where students actively explore geographic information rather than only receiving theoretical explanations (Firdaus & Yuliani, 2022).

Moreover, GIS is relevant to learning objectives in senior high schools, particularly in enhancing students' ability to understand spatial patterns and relationships. The integration of GIS in the learning process supports the development of students' digital literacy. Furthermore, it strengthens students' understanding of geographic concepts in a more practical manner (Saptorini, 2022).

Previous studies have highlighted the benefits of GIS in improving spatial thinking and student engagement. However, most of these studies focus on its effectiveness in ideal learning conditions and do not fully address the challenges of implementation in actual classroom settings. This study extends these perspectives by examining how GIS is applied in real school contexts, particularly when limitations in teacher competence and infrastructure are present.

2.3 Challenges in GIS Learning

Despite its potential, the implementation of GIS learning still faces various challenges in practice. These challenges arise from both internal and external factors that influence the learning process. Such constraints may hinder the effectiveness of GIS-based learning in achieving its educational objectives (Supuwiningsih, 2025).

From the teachers' perspective, limited skills in operating GIS software and lack of training constitute major obstacles in its implementation. Consequently, many teachers are not adequately prepared to integrate GIS into their teaching practices. This condition ultimately affects the overall quality of the learning process (Khairurraziq et al., 2024; Zulkarnain et al., 2023).

From the students' perspective, difficulties in understanding spatial concepts and low learning motivation are commonly encountered in GIS learning. These challenges are often caused by learning methods that remain dominated by theoretical approaches with limited practical activities. As a result, GIS is perceived as difficult and less relevant by students (Nuriyanto et al., 2022; Al Fauzi et al., 2022).

In addition, limited facilities such as computer laboratories, GIS software, and internet access hinder the implementation of GIS learning in schools. This condition is further exacerbated by curriculum limitations and the lack of institutional support in the learning process. As a result, GIS is often delivered theoretically with minimal practical exposure (Fadlan, 2023; Somantri, 2022; Zulkarnain et al., 2023).

Previous research has identified various constraints in GIS learning, including limited teacher competence, low student engagement, and inadequate facilities. However, these studies tend to examine these factors separately and do not fully explore how they interact in shaping the overall learning process. This study addresses this gap by analyzing the interconnected nature of these challenges within real classroom contexts.

3. METHOD

3.1 Research Design

This study employed a qualitative approach using a multi-site case study design to obtain a comprehensive and in-depth understanding of the challenges encountered in Geographic Information Systems (GIS) learning within real classroom contexts. The qualitative approach was considered appropriate as it allows the researcher to explore participants' experiences, perceptions, and interpretations in a more detailed and meaningful way. Through this approach, the complexity of teaching and learning processes can be captured holistically, particularly in identifying the factors that influence the implementation of GIS learning in schools (Moleong, 2019).

Furthermore, the multi-site case study design was applied across three different schools, namely SMA Negeri 3 Metro, SMA Muhammadiyah Ahmad Dahlan Metro, and MAN 1 Metro. These schools were selected purposively to represent different types of educational institutions, including public, private, and Islamic senior high schools. This variation was intended to provide richer data and a broader perspective regarding the challenges of GIS learning in diverse educational settings. By examining multiple sites, this design enables cross-case analysis to identify both similarities and differences in the patterns of challenges faced by teachers and students. In addition, it allows the researcher to draw more comprehensive conclusions and strengthen the validity of the findings through comparison across contexts (Yin, 2014).

In addition, this research design allows for a more comprehensive exploration of contextual factors that influence the implementation of GIS learning in each school. Differences in teacher competence, student characteristics, and the availability of supporting facilities may shape how GIS is taught and understood in the classroom. By examining these aspects across multiple sites, the study is able to capture both shared challenges and context-specific conditions that may not be visible in a single-site study.

Moreover, the use of a multi-site approach strengthens the analytical depth of the research by enabling cross-case comparisons. Through this process, recurring patterns can be identified while also highlighting unique variations among the schools, providing a more nuanced understanding of the phenomenon under investigation. This not only enhances the credibility of the findings but also supports the development of more grounded and context-sensitive interpretations regarding the challenges of GIS learning in different educational environments.

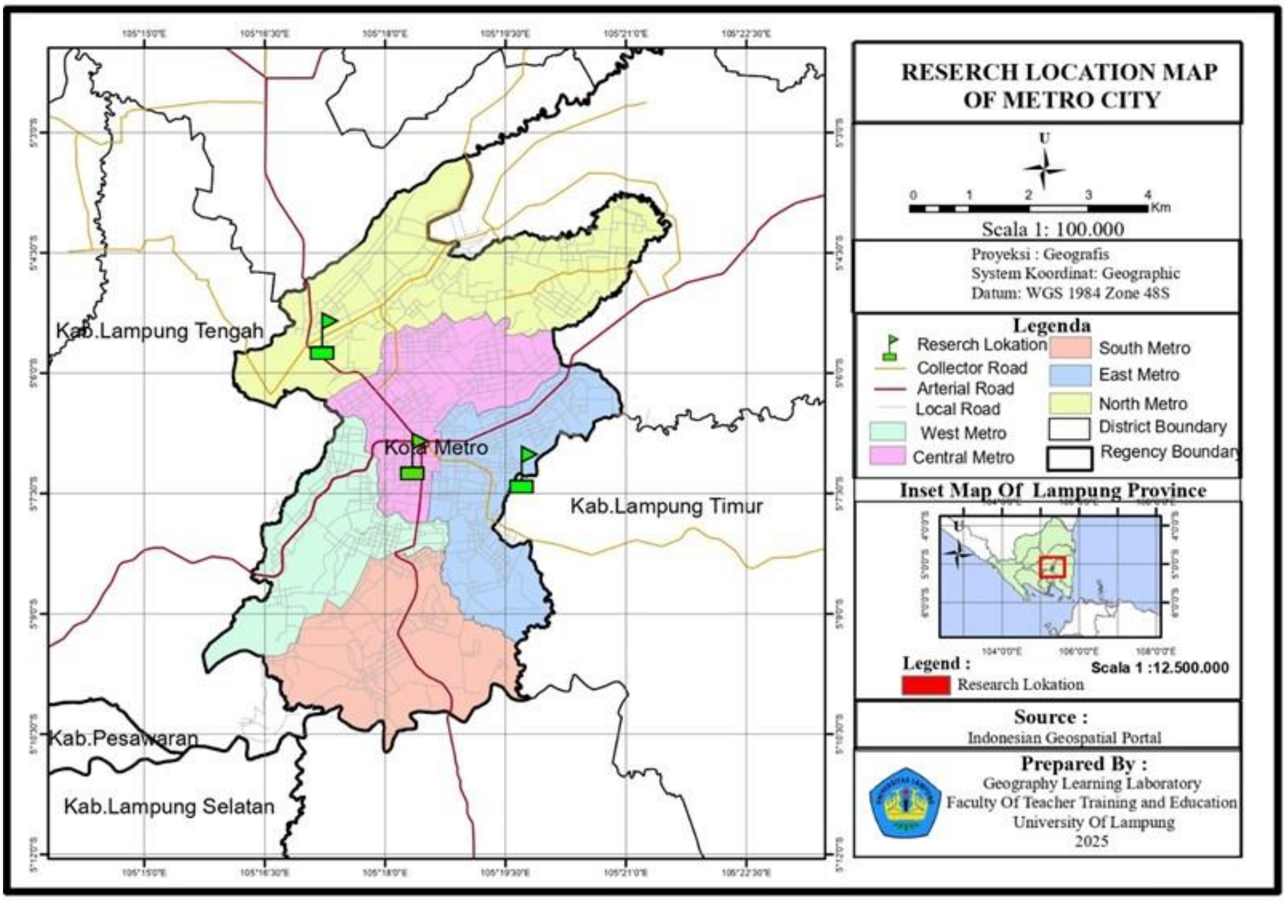

Figure 1. Map of the Research Location

Source: *Author's documentation (2025).*

3.2 Participants

The participants of this study consisted of geography teachers and students who were directly involved in GIS learning. They were selected using a purposive sampling technique based on criteria relevant to the research objectives. This approach ensured that the selected participants were appropriate for addressing the focus of the study.

Teacher participants were selected based on specific criteria, including teaching geography subjects that incorporate GIS material, having at least one year of teaching experience, and being directly involved in planning and implementing GIS learning. Meanwhile, student participants were selected from those who had learned GIS. They represented different levels of academic ability to provide varied perspectives in the study. The total number of participants in this study was 9, consisting of 3 geography teachers and 6 students. The research was conducted over a period of approximately three months.

3.3 Data Collection

Data were collected using three main techniques: interviews, observation, and documentation.Semi - structured interviews were conducted with teachers and students to explore their experiences and perceptions of GIS learning. Observation was carried out to examine the learning environment and classroom interactions. Documentation, such as lesson plans, teaching materials, and learning activities, was used to support and validate the data obtained from interviews and observations (Creswell, 2015).

3.4 Data Analysis

Data were analyzed using the interactive model proposed by Miles and Huberman (1994). This model consists of three main steps, namely data reduction, data display, and conclusion drawing. These stages were carried out systematically to ensure the validity and clarity of the research findings. Data reduction involved selecting and organizing relevant information from the collected data. In this process, coding was conducted by assigning labels to meaningful units of data obtained from interviews and observations. These codes were then grouped into categories based on similarities in meaning, which were further developed into broader themes to identify patterns across the data. Data display was conducted by presenting the data in a structured narrative form to facilitate interpretation. Finally, conclusions were drawn and continuously verified. This analytical process was carried out iteratively to ensure consistency and depth in interpreting the data. to ensure the validity and consistency of the findings trustworthiness

To ensure data validity, this study applied triangulation techniques, including source triangulation and method triangulation. Source triangulation was conducted by comparing information obtained from teachers and students, while method triangulation involved the use of multiple data collection techniques. These techniques included interviews, observation, and documentation (Moleong, 2019; Creswell, 2015).

4. RESULTS AND DISCUSSION

4.1 Research Findings

4.1.1 SMA Negeri 3 Metro

The findings indicate that GIS learning at SMA Negeri 3 Metro has not been fully implemented in a practical manner. Teachers generally understand basic GIS concepts; however, their technical skills in operating GIS software remain limited. As a result, learning tends to focus on theoretical explanations. Teacher participation in training is still limited and not continuous. Instructional strategies are predominantly lecture-based, with minimal use of technology. Students experience difficulties in understanding GIS concepts and show relatively low participation. Although computer facilities are available, limitations in software and institutional support hinder effective implementation.

4.1.2 SMA Muhammadiyah Ahmad Dahlan Metro

Similar patterns are observed at SMA Muhammadiyah Ahmad Dahlan Metro. Teachers have basic conceptual knowledge but limited technical competence in GIS applications. Training opportunities are minimal and not sustained. Teaching methods are still dominated by lectures, and the integration of digital tools remains limited. Students face challenges in understanding the material and tend to be less engaged. Infrastructure is available but not fully supportive, particularly in terms of software and technical resources.

4.1.3 MAN 1 Metro

At MAN 1 Metro, GIS learning also faces several constraints. Teachers demonstrate adequate conceptual understanding but limited practical skills. Training has been conducted but lacks continuity and impact. Instruction remains largely conventional, and student engagement is relatively low. While facilities are somewhat better, challenges related to software availability and institutional support persist.

4.2Results

This section presents a more detailed analysis of the findings from each research site. The discussion is organized based on three main aspects, namely teacher constraints, student constraints, and infrastructure and policy constraints. This structure aims to provide a deeper understanding of how GIS

In addition, the findings are interpreted by relating them to relevant theoretical perspectives and previous studies, in order to highlight broader patterns and meanings beyond the descriptive results presented earlier.

4.2.1 SMA Negeri 3 Metro

a. Teacher Constraints

The findings reveal that teachers at SMA Negeri 3 Metro possess only a basic conceptual understanding of GIS, which has not developed into operational competence in using GIS software such as ArcGIS or QGIS . As a result, GIS instruction is primarily delivered through theoretical explanations, without any integration of practical activities. This condition reflects a fundamental gap between knowledge and practice. Although teachers are familiar with GIS concepts, they lack the technical confidence and skills required to implement them in a classroom setting. This limitation not only affects how the material is delivered but also shapes the overall learning environment, which remains teacher- centered and passive. In such conditions, students are positioned as recipients of information rather than active participants in spatial inquiry.

Figure 2. Interview with teacher
Source: Author's documentation (2025).

b. Student Constraints

From the student perspective, the findings indicate that many students experience difficulties in understanding GIS material, particularly due to unfamiliar terminology and the abstract nature of spatial concepts. In addition, students reported that they have never been involved in practical activities using GIS tools.

Figure 3. Interview with student
Source: Author's documentation (2025).

c. Infrastructure and Policy Constraints

In terms of infrastructure, the school has computer laboratory facilities; however, they are not functionally ready to support GIS learning. The absence of GIS software, uncertain hardware specifications, limited laboratory access, and unstable internet connectivity all contribute to this limitation. These findings indicate that the issue lies not in the availability of facilities, but in their readiness and alignment with instructional needs. Technology-based learning requires not only physical infrastructure but also appropriate software, maintenance, and accessibility. Without these elements, the integration of GIS into classroom practice becomes impractical.

Figure 4. Facilities and Infrastructure
Source: Author's documentation (2025).

4.2.2 SMA Muhammadiyah Ahmad Dahlan Metro

a. Teacher Constraints

The findings show that teachers at this school have varying levels of GIS competence. Some have prior experience using GIS software during their university education, while others are limited to conceptual understanding . However, this competence has not been translated into classroom practice. This indicates a disconnect between prior knowledge and instructional implementation. Although teachers have been exposed to GIS, they are unable to apply it effectively due to external constraints. As a result, teaching remains focused on explanation using visual aids such as PowerPoint and digital maps, rather than direct engagement with GIS tools.

Figure 5. Interview with teacher
Source: Author's documentation (2025).

b. Student Constraints

Students demonstrate varying levels of understanding and interest in GIS. Some students find the material engaging when it is connected to real-world contexts, while others struggle, particularly with complex topics such as remote sensing and spatial data interpretation. This variation suggests that learning experiences are not evenly distributed. Students who are able to relate the material to real-life situations tend to develop better understanding, while others remain dependent on abstract explanations.

Figure 6. Interview with student
Source: Author's documentation (2025).

c. Policy and Infrastructure Constraints

The most significant constraint in this school lies in institutional policy and technological limitations. The use of Chromebook devices does not support GIS software installation, and school regulations restrict students from using personal electronic devices . These conditions create a structural barrier to GIS implementation. While the school may support innovation in principle, its policies limit access to the necessary tools for technology-based learning.

Figure 7. Facilities and Infrastructure
Source: Author's documentation (2025).

4.2.3 MAN 1 Metro

a. Teacher Constraints

Teachers at MAN 1 Metro demonstrate a general understanding of GIS concepts; however, their knowledge has not been updated and remains based on what they learned during university. One teacher described their understanding as outdated . This finding highlights the critical role of continuous professional development. GIS is a rapidly evolving field, and without regular training, teachers are unable to keep up with technological advancements. As a result, their teaching practices remain static and disconnected from current developments.

Figure 8. Interview with teacher
Source: Author's documentation (2026).

b. Student Constraints

Students face difficulties in understanding GIS concepts and have no opportunity to engage in practical activities . Consequently, learning is limited to theoretical explanation, which restricts the development of spatial analysis skills. This condition reinforces the importance of practice in GIS learning. Spatial thinking is not developed through memorization but through interaction with spatial data.

Figure 9. Interview with student
Source: Author's documentation (2025)

c. Infrastructure Constraints

The findings indicate that although some technological facilities are available, they are not adequate to support GIS learning. Hardware specifications are insufficient, and GIS software is not provided. This suggests that infrastructure is present but not appropriate for instructional needs. GIS applications require specific technical capabilities, and without them, practical implementation becomes impossible.

Figure 10. Facilities and Infrastructure
Source: Author's documentation (2026).

4.3 Discussion of Cross-Site Findings

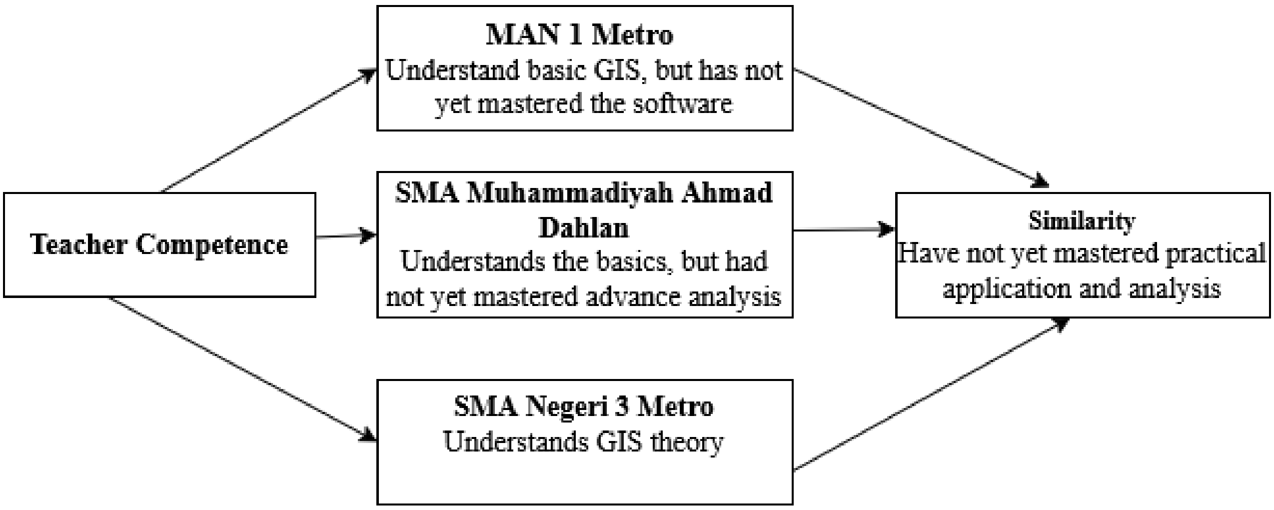

Figure 11. Cross-Site Analysis of Teacher Competence in GIS Learning
Source: Author's Analysis (2025).

The cross-site findings indicate that teacher competence in GIS learning demonstrates a relatively similar pattern across the three research locations. As presented in Figure 11, most teachers already possess a basic understanding of GIS concepts; however, their technical ability to operate GIS software remains limited. Across the three schools, this limitation is reflected in the minimal use of GIS applications during the learning process. Teachers tend to avoid practical implementation due to a lack of confidence and technical mastery. Although there are slight differences in experience levels among teachers, the overall pattern shows that GIS learning is still predominantly conceptual rather than practical. This suggests that improving technical competence is essential for enabling more effective and application-based GIS instruction.

4.3.1 Cross-Site Analysis of Teacher Training in GIS Learning

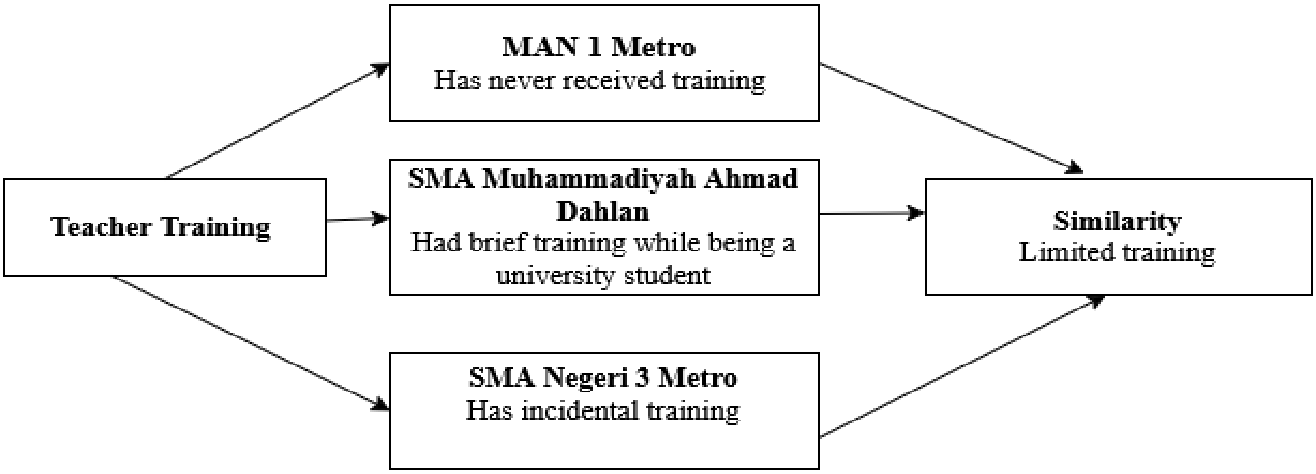

Figure 12. Cross-Site Analysis of Teacher Training in GIS Learning
Source: Author's Analysis (2025).

Teacher training emerges as another critical aspect influencing GIS learning implementation. Based on Figure 4.5, the findings reveal that access to training is still limited and uneven across the three schools. Some teachers have participated in training programs; however, these are generally not continuous or sufficiently practice-oriented. As a result, the impact of such training on improving teaching competence remains limited. From a cross-site perspective, all schools face similar challenges in terms of the lack of structured professional development programs. This condition highlights the need for more systematic and sustainable training initiatives to support teachers in implementing GIS learning effectively.

4.3.2 Cross-Site Analysis of Instructional Strategies in GIS Learning

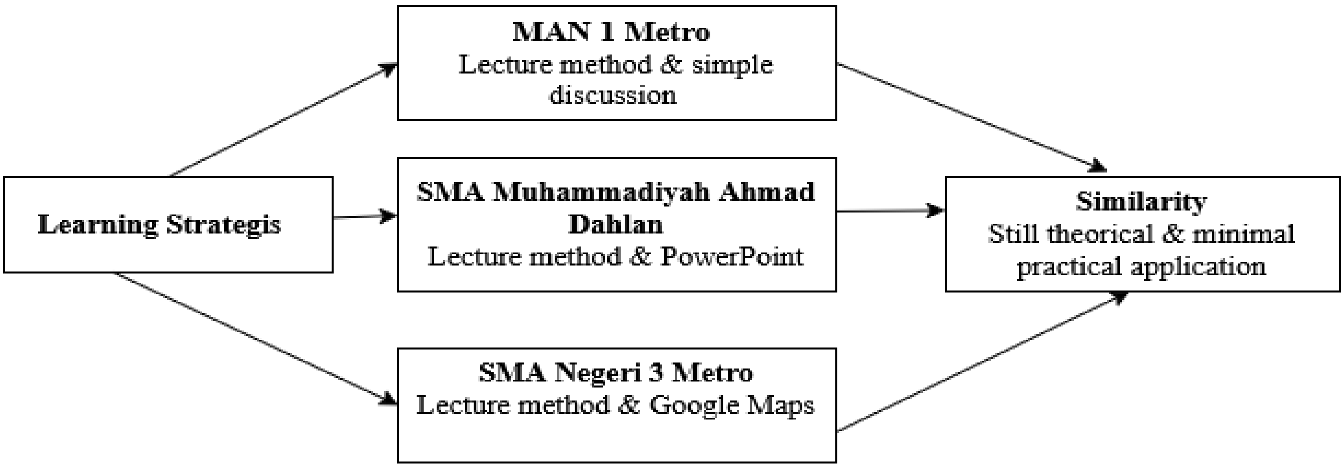

Figure 13. Cross-Site Analysis of Instructional Strategies in GIS Learning
Source: Author's Analysis (2025).

Instructional strategies used in GIS learning also show consistent patterns across the research sites. As illustrated in Figure 13, teaching methods are still largely dominated by lectures and basic discussions. Across all three schools, the integration of interactive and technology-based learning remains minimal. Although some teachers attempt to incorporate digital tools, these efforts are not yet fully optimized to support student-centered learning. This indicates that the transformation from conventional teaching methods to more innovative and practice-oriented approaches has not been fully achieved.

4.3.3 Cross-Site Analysis of Student Learning Interest

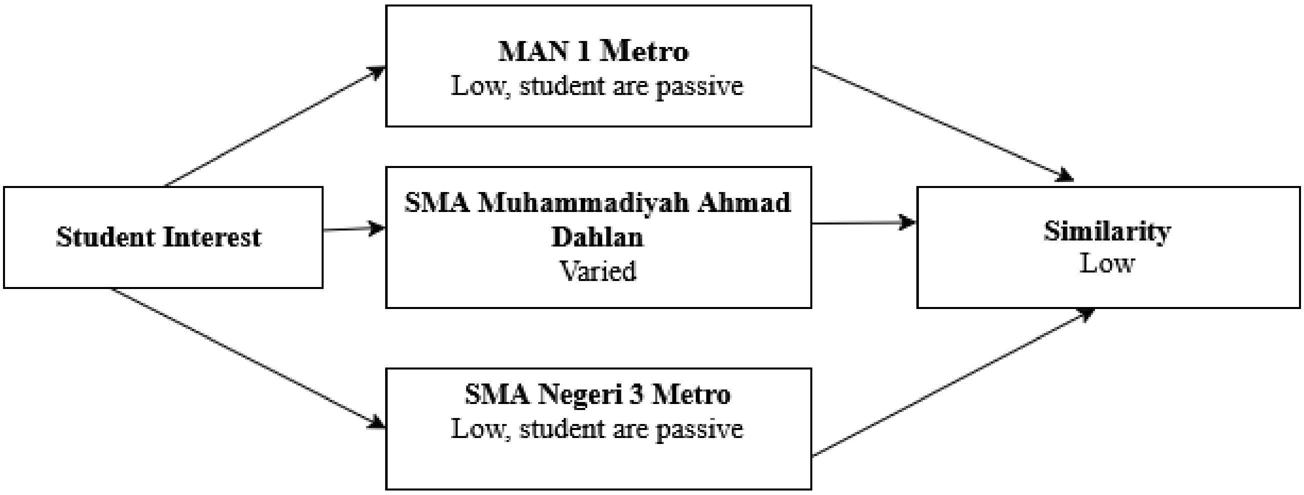

Figure 14. Cross-Site Analysis of Student Learning Interest in GIS
Source: Author's Analysis (2025).

Student learning interest in GIS also reflects similar tendencies across the three research sites. As shown in Figure 14, student engagement in GIS learning tends to be relatively low. This condition is closely related to the instructional approaches used by teachers. In classrooms where lecture-based methods dominate, students tend to be more passive and less motivated to participate. Although there are slight variations in student responses, particularly when digital tools are introduced, the overall level of engagement remains limited. This suggests that increasing student interest requires not only technological integration but also more interactive teaching strategies.

4.3.4 Cross-Site Analysis of Facilities and Infrastructure

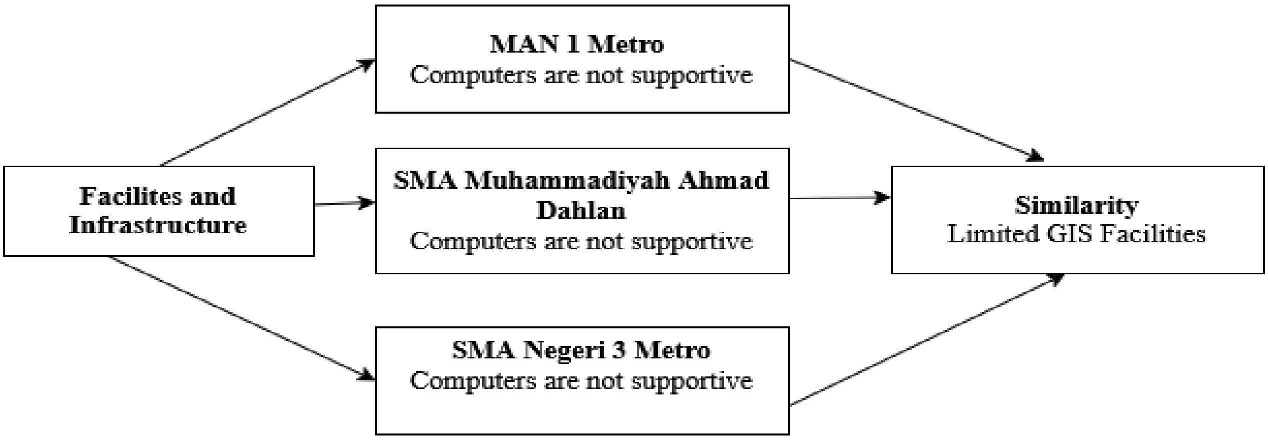

Figure 15. Cross-Site Analysis of Facilities and Infrastructure for GIS Learning
Source: Author's Analysis (2025).

Facilities and infrastructure represent another important factor affecting GIS learning. Based on Figure 4.8, it is evident that while some schools have basic facilities such as computer laboratories, the availability of GIS software and adequate hardware is still insufficient. Across the three schools, similar constraints are observed, particularly related to limited access to licensed software and inadequate computer specifications. These limitations restrict the implementation of practical GIS activities. Thus, the cross-site findings indicate that infrastructural limitations remain a common challenge in supporting GIS-based learning.

4.3.5 Cross-Site Analysis of Institutional Support and Policy

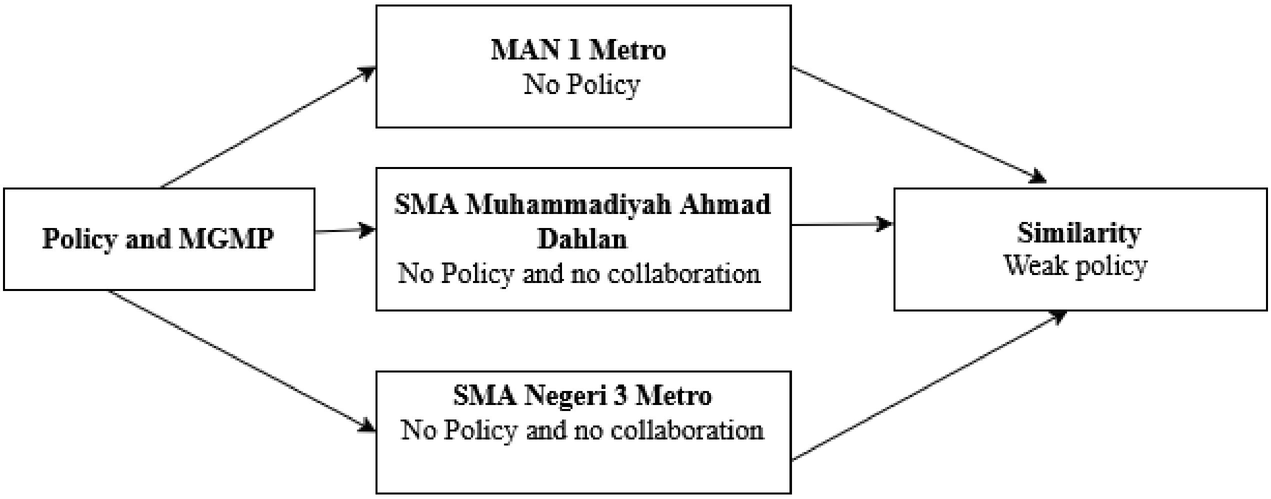

Figure 16. Cross-Site Analysis of Institutional Support and Policy in GIS Learning
Source: Author's documentation (Analysis).

Institutional support and policy also play a significant role in shaping GIS learning implementation. As illustrated in Figure 16, there is a lack of specific policies supporting the integration of GIS into the curriculum across all research sites. Support in the form of training programs, funding, and curriculum development is still limited. Additionally, professional forums such as MGMP have not been fully utilized to enhance teacher competence in GIS. From a cross-site perspective, this indicates that institutional constraints are systemic and require coordinated efforts at the school and policy levels.

4.3.6 Synthesis of Cross-Site Findings

The overall cross-site analysis demonstrates that each aspect teacher competence, training, instructional strategies, student interest, facilities, and institutional support is interconnected. Limitations in one aspect tend to influence others, creating a cycle of constraints that hinder the effective implementation of GIS learning. Therefore, addressing these challenges requires a comprehensive and integrated approach.

4.4 Discussion

4.4.1 Teacher Constraints

The findings indicate that teachers possess basic conceptual understanding of GIS but demonstrate limited technical competence in its practical implementation. This limitation is reflected in the tendency of teachers to emphasize theoretical explanations rather than facilitating hands-on GIS activities in the classroom, resulting in learning that does not fully represent the applied nature of GIS.

As a consequence, students have limited opportunities to develop practical spatial analysis skills.

This condition is likely influenced by the lack of continuous professional training and insufficient institutional support. Although teachers may have been introduced to GIS during their academic preparation, such exposure is often not followed by sustained skill development, making it difficult for them to confidently implement GIS in teaching. In addition, limited time and workload pressures further reduce opportunities for teachers to explore and apply GIS tools in classroom settings.

This finding is consistent with Bernhäuserová et al. (2022), who highlight that limited practical experience and insufficient training significantly constrain the effective implementation of GIS in education. Similarly, Kerski (2020) emphasizes that successful GIS integration requires not only conceptual understanding but also strong technical competence supported by institutional readiness. These findings indicate that improving teacher capacity is a critical factor in enhancing GIS learning effectiveness.

4.4.2 Student Constraints

The findings show that students experience difficulties in understanding GIS concepts and demonstrate low engagement during the learning process. This is reflected in their limited ability to interpret spatial data and their passive participation in classroom activities, which reduces the effectiveness of learning. As a result, GIS is often perceived as a complex and less engaging subject.

This condition may be explained by the dominance of theoretical teaching approaches that limit students' opportunities to interact directly with spatial data. Without hands-on experience, students find it difficult to connect abstract concepts with real-world applications, leading to superficial understanding. Furthermore, the lack of interactive learning environments contributes to decreased motivation and participation among students.

This result supports Duarte et al. (2022), who argue that spatial thinking develops more effectively through active engagement with geospatial tools. In addition, Firdaus and Yuliani (2022) emphasize that meaningful GIS learning occurs when students are directly involved in practical and exploratory activities. These findings highlight the importance of student-centered and practice-based learning approaches in GIS education.

4.4.3 Infrastructure Constraints

The findings reveal that infrastructure limitations remain a significant barrier to the implementation of GIS learning across the observed schools. Although some schools provide basic facilities such as computer laboratories, these are often insufficient to support effective GIS instruction. Limitations in hardware capacity and access to appropriate software restrict the implementation of practical learning activities.

This issue is likely caused by a mismatch between available facilities and the technical requirements of GIS applications. GIS software requires adequate computing specifications and proper system support, which are not always available in school environments. As a result, teachers face difficulties in integrating GIS into their teaching practices even when they have the intention to do so.

This finding aligns with Kerski et al. (2013), who identify infrastructure readiness as a key factor influencing GIS integration in education. Furthermore, González et al. (2020) emphasize that limited access to technology and geospatial resources remains a major challenge in many educational contexts. These findings reinforce the importance of institutional support in facilitating technology-based learning.

The three main constraints identified in this study teacher competence, student engagement, and infrastructure limitations are closely interconnected and influence one another. Limitations in teacher competence affect instructional quality, which in turn impacts student understanding and engagement in GIS learning. At the same time, inadequate infrastructure further restricts both teaching practices and learning experiences, creating a cycle that hinders the effective implementation of GIS in schools. Therefore, addressing these challenges requires integrated efforts involving teacher training,improved learning strategies, and stronger institutional support.

5. CONCLUSION

In addition, this study provides several scientific contributions, particularly in offering a deeper understanding of the challenges in implementing GIS learning through a multi-site perspective. By examining different types of schools, this study highlights consistent patterns of constraints related to teacher competence, student engagement, and infrastructure readiness, thereby enriching the existing literature on GIS education in diverse educational contexts. Furthermore, several practical recommendations can be proposed based on the findings of this study. For schools, it is important to enhance institutional support by providing adequate infrastructure, including access to GIS software and sufficient technological facilities to support practical learning. For teachers, continuous professional development and training programs are necessary to improve both conceptual and technical competence in GIS implementation, enabling more effective and interactive learning processes. For future research, it is recommended to explore the effectiveness of specific instructional strategies or interventions in improving GIS learning outcomes. Further studies may also involve a larger number of participants or different educational levels to provide more comprehensive insights and strengthen the generalizability of the findings.

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