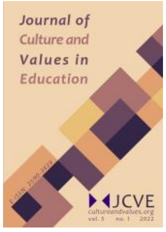

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A Review towards Enhancing Geospatial Technologies in South African Rural Education

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ABSTRACT
This study investigates the geospatial technologies in the South African rural schools. Despite the increasing importance of geospatial technologies, there is inadequate research examining their integration into rural education curricula. This gap in the literature raises questions about the effectiveness of current pedagogical practices in fostering proficiency in utilizing geospatial technologies among students preparing for careers in this field. The rationale behind this study lies in recognizing the critical role that geospatial literacy plays in contemporary professional practice. By identifying effective pedagogical practices, educators can enhance teaching and learning experiences, ultimately improving student outcomes, and the study addresses the broader societal need for skilled geospatial professionals in South African rural schools. The study employed a Systematic Literature Review (SLR) on geospatial technologies in South African rural schools. In addition, the inclusion and exclusion research design were adopted for the study, while the social constructivism theory guided the study. The review process resulted in a detailed analysis of 54 relevant articles utilized for the study. The findings reveal that the challenges to utilizing GIS in South African rural education curricula are multifaceted, encompassing infrastructural deficiencies, limited access to technology and resources, lack of teacher training, curriculum integration issues, The findings contribute to understanding how proficiency in geospatial technologies can be enhanced through innovative teaching methods, addressing the growing demand for geospatial skills in various professional domains. This study recommends the enhancement of geospatial technologies rural education programs and standardizing geospatial curriculum frameworks, hands-on learning experiences, and interdisciplinary collaborations.

KEYWORDS
Pedagogy; geoinformation technologies; rural education; teaching and learning.

INTRODUCTION

According to Olatoye et al. (2022), geospatial technologies are essential in modern societies, significantly influencing decision-making processes at both global and regional levels. These tools provide valuable insights into spatial relationships and patterns, aiding in urban planning, environmental management, and strategic interventions (Mkhongi & Musakwa, 2020). In South Africa, a nation with diverse landscapes and complex socio-economic dynamics, the integration of geospatial technologies is particularly important (Lembani et al., 2020). This study aims to explore the global significance of geospatial technologies, regional challenges and opportunities, and the context of South African rural education to enhance proficiency in geospatial technologies. Globally, geospatial technologies have applications in disaster response, climate change monitoring, humanitarian aid, and sustainable development, highlighting the need for skilled professionals in geospatial analysis (Mhlongo et al., 2023). This global demand emphasizes the importance of equipping students in rural education institutions with the necessary skills in geospatial technologies to succeed in a rapidly evolving landscape (Csachova, 2020). Regionally, South Africa's unique context of diverse ecosystems, socio-cultural dynamics, and economic disparities requires accurate spatial information and advanced analytical tools for effective resource management (Bernhäuserová et al., 2022). However, challenges such as resource mismanagement underscore the need for robust geospatial expertise in rural education. Integrating geospatial technologies into South African rural education curricula presents both opportunities and challenges (Mhlongo et al., 2023). Although several institutions offer geospatial programs, aligning educational offerings with industry demands is crucial. Issues such as access to technology, faculty expertise, and curriculum relevance may impede effective geospatial education delivery. By critically examining existing pedagogical practices and learning outcomes, this study aims to develop strategies for improving geospatial technology proficiency in South African rural education, addressing broader socio-economic and environmental challenges.

Background to the Study

Geo-Spatial Information Science (GSIS) is recognized globally as a multifaceted technology with a powerful visual dimension, offering significant potential for making highly informed spatial decisions (Olatoye, 2020). Initially developed for scientific land management in Canada during the 1960s, GIS has since expanded into various fields (Ma et al., 2023). However, Mkhize (2023a) argues that GIS has not been a central component of geography education, leading to its slow diffusion in secondary schools. Similarly, Chisango et al. (2020) advocate for integrating GIS into education. The Environmental Systems Research Institute (ESRI) has been instrumental in popularizing GSIS, extending its applications from environmental monitoring to education. GIS is considered essential for modern spatial decision-making tools (Olatoye et al., 2022). Musakwa (2017) describes GSIS as the study of computerized systems for capturing, storing, analyzing, managing, and presenting spatially referenced data. GIS combines hardware, software, data, methods, and people to prepare, interpret, and present spatial data (Olatoye, 2020). The visual dimension provided by geospatial tools facilitates communication and discourse among stakeholders through maps.

Education, as part of the Sustainable Development Goals, is crucial for improving individuals' quality of life (De Guimarães et al., 2020; Dube et al., 2023; Moloi et al., 2023). As a fundamental human right, education is essential for realizing other human rights and accessing broader social, economic, cultural, and political benefits. In the context of GIS and education, early proponents like Goodchild and Kemp believed that increasing accessibility to GIS data would benefit students by enhancing their interest in geography and offering career prospects (Hintermann et al., 2020). According to Dolan (2020), there are two major dimensions to the interactions of GIS and education namely: learning about GIS as well as learning through GIS. learning about GIS are depicted by the training programs that prepare individuals to become GIS professionals, while learning through GIS are the educational tools that harness the development of spatial capabilities. Geography standards include GIS knowledge at two levels: GIS application, which involves higher-order thinking like decision-making and problem-solving, and GIS awareness, which introduces basic GIS concepts and functions (Aliman et al., 2024; Rees et al., 2020). The introduction of GIS in secondary schools is supported for several reasons: it is increasingly important in the workplace, particularly in rural communities; it is a critical tool for decision-making and environmental analysis; it motivates students' interest in geography, thereby improving geographic education; and it encourages careers in science and engineering. GIS is particularly relevant in the context of the fourth industrial revolution. According to Rushton, (2021), students' performance in South African schools has been on the decline since 2014, despite its importance for advancing GIS education. GSIS is taught from grades 10 to 12 in geography classes, as mandated by the Department of Basic Education (Sebastián et al., 2024). The 2011 Curriculum and Assessment Policy Statements (also abbreviated as CAPS) document emphasizes the integration of GIS skills from grade 10 to 12. However, there is limited research on the review, impact, and success of GIS education in South African high schools, with most studies conducted in America and Europe. This study aims to provide a pedagogical review to enhance geospatial technologies in South African rural education.

Statement of the Research Problem

Hintermann et al. (2020) highlight the growing importance of geospatial technologies in rural education, emphasizing their critical role in modern environmental management and policymaking (Sharma et al., 2023). Despite their increasing use in professional practice, there is a significant lack of research on their integration into rural education curricula (Wahyuningtyas et al., 2020). This gap in the literature is not just an academic issue; it reflects a crucial oversight in preparing future professionals for the field's evolving demands. The absence of comprehensive studies on incorporating geospatial technologies into rural education raises important questions about the effectiveness of current teaching methods (Liu et al., 2023). Without a solid foundation in geospatial technologies and practical experience with relevant tools and methodologies, students aiming for careers in rural education may be illprepared to handle real-world challenges. Moreover, the lack of exposure to these technologies during their education could limit their ability to contribute effectively to sustainable rural education policies.

Shikalepo (2020) underscores the importance of understanding the challenges and opportunities associated with teaching geospatial technologies in rural education to address the existing skills gap and ensure the competency of future professionals. By identifying barriers such as limited access to technology, inadequate faculty training, or outdated curricula, educators and policymakers can take proactive steps to revitalize and modernize rural education programs (Wahyuningtyas and Idris, 2020). Additionally, leveraging emerging opportunities like open-source software and online learning platforms can enhance the accessibility and effectiveness of geospatial education, empowering students to become proficient practitioners in their field. Bridging the gap between theory and practice in geospatial education is essential for developing skilled professionals capable of tackling the complex challenges facing rural education. Investing in innovative pedagogical approaches, fostering interdisciplinary collaborations, and embracing technological advancements can equip students with the knowledge, skills, and competencies needed to thrive in the rapidly changing landscape of environmental governance and resource management (Sharma et al., 2023).

Research Question

How are geospatial technologies utilized in South African rural education?

Aim of the Study

This study aims at reviewing geospatial technologies in the South African rural education.

Rationale of Study

According to Ma et al. (2023), geospatial technologies, including GIS, remote sensing, and spatial analysis, have the potential to revolutionize educational practices and improve learning outcomes on global, regional, and local scales, particularly within South Africa's rural education system. Globally, these technologies are increasingly valued for their ability to create interactive and engaging learning experiences, fostering critical spatial thinking skills among students (Fleischmann et al., 2020). In Africa, integrating geospatial technologies into educational curricula can enrich learning by providing practical, hands-on applications of geographic and scientific concepts, thereby making abstract ideas more concrete (Olatoye, 2020). In South Africa, where rural education faces significant challenges due to limited resources, infrastructural disparities, and socio-economic constraints, these technologies can help bridge educational gaps by giving rural students access to advanced learning tools (Mkhize, 2023a). This review aims to address resource constraints by identifying and proposing solutions to challenges such as inadequate teacher training and insufficient ICT infrastructure. Through robust evidence and insights, the study seeks to inform policy and practice, guiding educational leaders and policymakers in effectively integrating geospatial technologies into the rural education system (Lee et al., 2021; Mkhize, 2023b). Additionally, these technologies can support sustainable development by equipping students with essential skills for environmental management, urban planning, and disaster response, aligning educational outcomes with broader societal goals. Furthermore, fostering career opportunities is a significant benefit, as proficiency in geospatial technologies can open new pathways for rural students in fields such as environmental science, urban planning, and GIS analysis (Chisango et al., 2020). This review examines how geospatial education can be tailored to meet workforce needs, contributing to the economic development of rural communities. Hence, this study provides a comprehensive review of integrating geospatial technologies in South African rural education, identifying best practices, challenges, and opportunities. It offers valuable recommendations to enhance proficiency in geospatial technologies and improve educational outcomes, ultimately promoting a more equitable and effective education system within South Africa and similar rural contexts globally and regionally.

Significance of the Study

This research has significant implications for both academia and industry (Liu et al., 2023). The findings provide valuable insights into how geospatial technology literacy can be integrated into rural education and curricula, thereby better preparing students for workforce demands. By identifying effective pedagogical practices, educators can enhance teaching and learning experiences, leading to improved student outcomes. Additionally, the study addresses the broader societal need for skilled professionals in geospatial technologies, contributing to economic development and sustainable natural resource management in South Africa. Social Constructivism emphasizes the importance of social interaction and context in constructing knowledge. In the context of geospatial literacy, this framework suggests that learning occurs through active engagement with others and the environment, as individuals build their understanding of spatial concepts through interaction with geospatial technologies, educational resources, and social discourse.

METHODOLOGY

The study utilized a Systematic Literature Review (SLR) to collect evidence from a diverse array of studies. As noted by Tashakkori and Teddlie (2021), an SLR is a thorough, methodical, and replicable method for identifying, assessing, and synthesizing existing research on a specific topic or question. This process involves a detailed and pre-defined search strategy, which includes selecting relevant databases, setting inclusion and exclusion criteria, and using standardized methods to evaluate the quality of the studies. The aim of an SLR is to minimize bias by adhering to a rigorous and transparent procedure, thereby providing a reliable and objective summary of the available evidence. This type of review is essential for informing policy, practice, and future research by identifying gaps in the current knowledge and offering a consolidated overview of what is known on the subject.

Review Process: This systematic review followed the guidelines provided by Laher and Hassem (2020), involving five key steps. The first step was framing the research question: "How can geospatial technologies be effectively integrated into rural education in South Africa?" The second step involved identifying relevant literature through search strategies and documenting the findings. The third step was assessing the quality of the identified studies. The fourth and fifth steps were interpreting and summarizing the information, respectively.

Search Strategy: The search strategy involved three steps:

Finding Keywords: Relevant keywords related to the topic were selected to ensure specificity and relevance to the systematic literature review.

Formation of Search Strings: Two search strings were used: “rural education OR school OR learning OR teaching OR class* OR education system AND GIS technology* AND South Africa." The first search string aimed for broad results, covering any papers mentioning the main subjects. The second search string refined the results to focus specifically on papers combining the keywords related to GIS technology and rural education in South Africa. This method ensured comprehensive coverage while allowing for targeted exploration of specific subtopics.

Selecting Sources: Four databases were chosen for their reliability and high-quality research output: Scopus, Web of Science, JSTOR, and Google Scholar.

Ensuring Reliability and Viability: To ensure the reliability and viability of the SLR methodology, a detailed protocol with predefined inclusion and exclusion criteria was developed to promote transparency and avoid duplication.

Inclusion and Exclusion Criteria:

From the initial database search, 92 papers were identified through keywords. After excluding 15 articles that were not aligned with the topic, 77 papers remained. Further review eliminated 38 articles that were not relevant, resulting in 49 articles. An additional 5 articles were added based on eligibility, culminating in 54 articles used for the study.

Quality Assessment Criteria:

The 92 papers were thoroughly reviewed against quality assessment questions, with each question scored as 1 for yes, 0 for no, and 0.5 for partial. Papers scoring 2 or more points were included in the final collection. Those scoring below 2 were re-evaluated by a team member, and those still scoring less than 2 were excluded.

Document Search Strategy:

After compiling the final collection, each article was linked to its respective database.

Snowballing:

In academic research, snowballing involves expanding a literature review by following references from identified sources. Starting with initial keywords or sources, the author examined references to find additional related sources. This iterative process continued, leading to the discovery of more relevant literature. Snowballing was particularly useful for uncovering lesser-known or recent studies and for researching niche topics. The author initially identified 92 articles, excluded 15, and thoroughly reviewed the remaining 77 articles. After quality assessment, 38 articles were excluded, and 5 were added for eligibility, resulting in 54 articles used in the study. Figure 1 illustrates the Systematic Literature Review process adopted for the study.

Figure 1.

Flow Diagram Depicting the Systematic Literature Review (SLR) Adopted for the study.

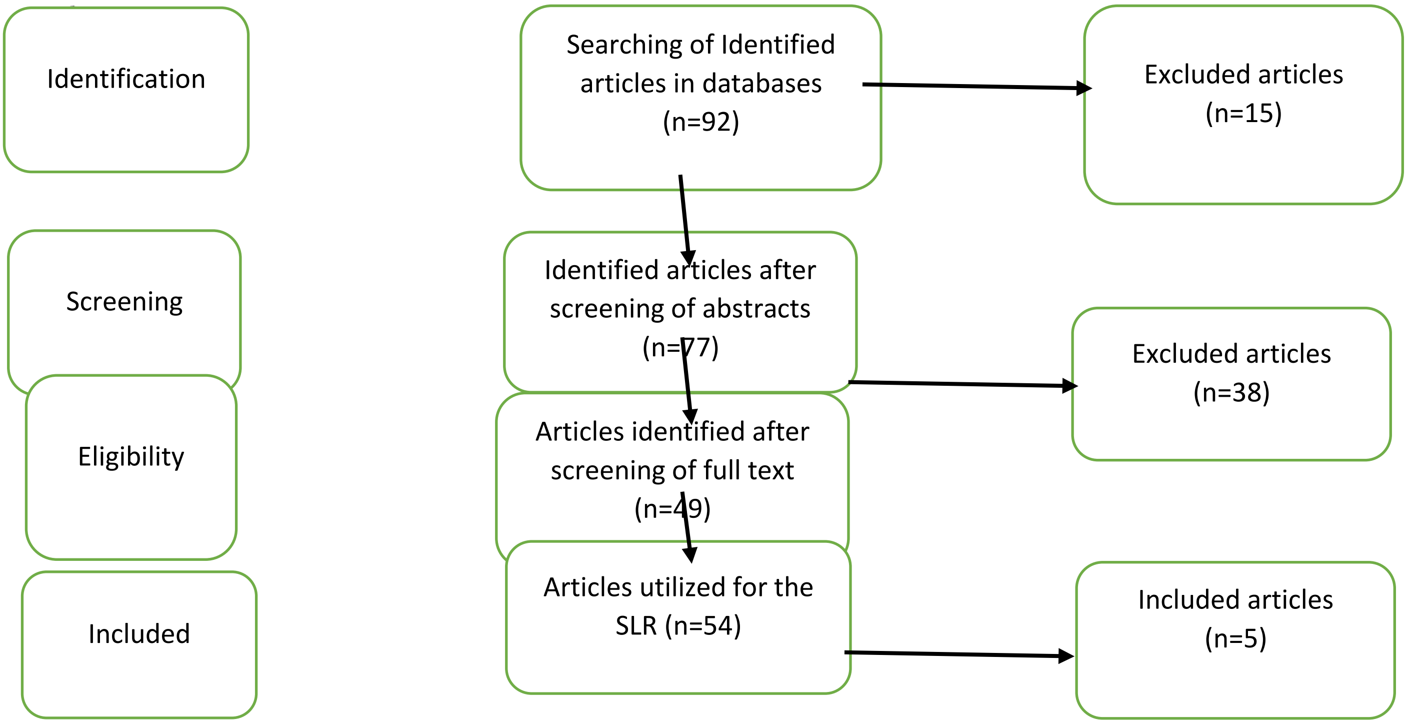


Figure 1 illustrates the SLR methodology utilized for the study. The selection process involved three screening phases: initial screening based on titles, followed by abstracts, and finally full-text review. Articles had to meet specific criteria: (1) published within the last ten years (2) written in English, (3) focused on geospatial technologies in South African rural education, and (4) peer reviewed. To maintain accuracy and impartiality in the screening process, detailed records that were derived yielded a total of 92 articles. In the title and abstract screening phase, 15 articles were excluded for not addressing geospatial technologies in South African rural education, leaving 77 articles. Further exclusions were made for research focused on higher education or purely online learning institutions, and 38 articles were excluded, resulting in 49 remaining articles. Studies conducted outside South Africa were also excluded. Articles containing theoretical information or teaching practices not directly answering the research question were excluded unless their relevance was uncertain, in which case they were retained for further inspection. Notes were taken for each article, including title, aims and objectives, research questions, methodology, sample, analysis, and findings to ensure relevance. Each article was assessed using the Critical Appraisal Skills Checklists for quantitative and qualitative studies to evaluate internal validity, external validity, relevance, originality, and ethical compliance (Laher & Hassem, 2020). Inclusion criteria was applied to select literature focusing on geospatial technologies' integration in rural education contexts in South Africa, including studies on pedagogical approaches, challenges, successes, and recommendations, and 5 articles were added based on these criteria, yielding 54 articles. The inclusion criteria added studies that were directly relevant to the research topic, as supported by Coe et al. (2021).

THEORETICAL FRAMEWORK

Social Constructivism Theory

According to Brau, (2020), Social Constructivism is a learning theory that emphasizes the role of social interaction and context in the construction of knowledge. According to this theory, individuals actively construct their understanding of the world through their experiences, interactions with others, and engagement with cultural artifacts and tools. Unlike traditional cognitive theories that focus on individual learning processes, Social Constructivism highlights the importance of collaboration, dialogue, and shared experiences in shaping learning outcomes. As supported in the literature by Tan and Ng, (2021), key principles of Social Constructivism that can inform the theoretical framework for this study include:

Active Learning: Students actively engage with geospatial technologies, such as GIS software and remote sensing tools, to explore spatial relationships and patterns within the context of rural education. By manipulating data and interpreting spatial information, learners construct their understanding of geospatial concepts and their applications in real-world scenarios.

Scaffolding: Educators provide scaffolding support to guide students' learning experiences, gradually withdrawing assistance as learners develop their skills in utilizing geospatial technologies. This could involve structured activities, problem-solving tasks, and collaborative projects that enable students to build upon their existing knowledge and expertise (Roth et al, 2023).

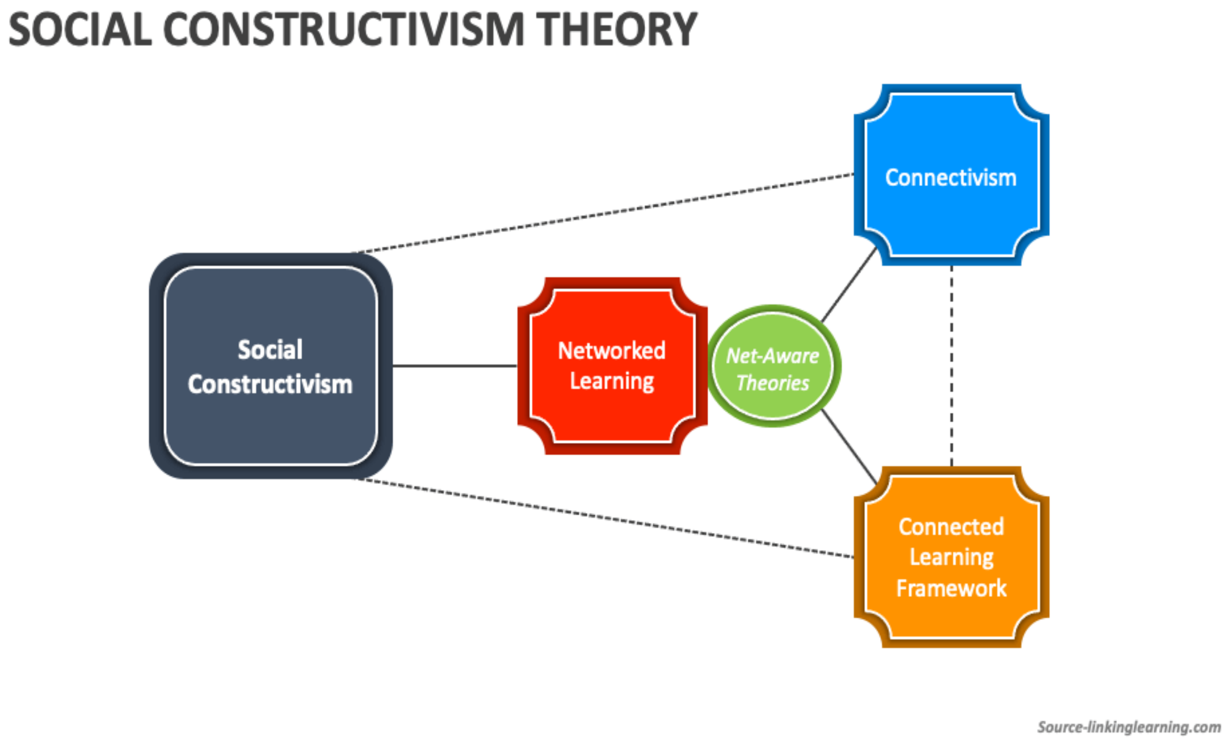
Authentic Tasks: According to Tan and Ng, (2021), learning tasks are designed to mirror authentic challenges encountered in rural education, allowing students to apply geospatial technologies in practical contexts. By working on real-world projects, rural learners can gain relevance in their utilization of geospatial technologies and the potential impact of their skills on environmental decision-making (Wahyuningtyas and Idris, 2020).

Collaborative Learning: Collaboration among students, teachers, and industry professionals fosters a supportive learning environment where knowledge exchange and peer interaction play central roles. Through collaborative endeavors, learners benefit from diverse perspectives, collective problem-solving, and shared experiences that enrich their understanding of geospatial technologies and their applications (Shikalepo, 2020).

Reflective Practice: Reflection is integrated into the learning process, encouraging students to critically evaluate their experiences, assumptions, and problem-solving strategies (Simasiku, 2020). By reflecting on their geospatial learning journey, learners develop metacognitive awareness and adapt their approaches to future challenges in rural education. By adopting a Social Constructivist framework, educators can design pedagogical interventions that promote active learning, collaborative inquiry, and authentic engagement with geospatial technologies in the context of South African rural education. This theoretical perspective underscores the dynamic interplay between individual cognition, social interaction, and environmental context, highlighting the importance of holistic approaches to geospatial education and literacy enhancement.

Figure 2.

Social Constructivism Theory



Application Of the Social Constructivism Theory to the Study

Applying Social Constructivism Theory to this study, on enhancing geospatial technologies in South African rural education involves understanding how learners construct knowledge through social interactions and cultural context. This theory suggests that learning is fundamentally a social process, where knowledge is jointly constructed through collaboration, conversation, and collective experiences. In the context of rural South African education, where resources and access to advanced technologies might be limited, introducing geospatial technologies should be accompanied by pedagogical strategies that foster collaborative learning environments (Shikalepo, 2020). Teachers can facilitate group projects that encourage students to use geospatial tools to solve local geographical issues, thereby making learning more relevant and engaging (See et al., 2022). For instance, students could work together to map local resources or track environmental changes, using these technologies to address real-world problems they observe in their communities. Additionally, incorporating culturally relevant content and local examples can help students connect new technological skills with their lived experiences, thus enhancing their understanding and retention. This approach not only grounds abstract technological concepts in the students' everyday realities but also promotes a sense of ownership and relevance in their learning. By creating a community of learners who actively engage with and support each other in using geospatial technologies, educators can improve both the technological proficiency and the overall educational outcomes for students in these rural areas (Their et al., 2021). This communal learning approach can also build students' confidence and motivation, as they see the direct impact of their collaborative efforts on their surroundings, thereby fostering a deeper and more sustained engagement with the educational material.

LITERATURE REVIEW

A Review of Geospatial Technologies in the South African Rural Education

According to Ridha and Kamil (2021), a Geographic Information System (GIS) serves as a sophisticated software platform designed to handle geographical information and analyze complex spatial relationships (Kurowska et al., 2020). It integrates various geographical features, such as maps, satellite images, and terrain models, with additional datasets containing attribute information. This integration enables GIS to create comprehensive and interactive maps that can be utilized to analyze and solve real-world geospatial problems (Usmani et al., 2020). The geographic aspect of GIS is fundamental, as it involves data that is directly linked to specific locations on the Earth's surface (Ali, 2020). This geospatial data often includes coordinates, boundaries, and other geographic identifiers, allowing users to precisely locate and visualize spatial phenomena. Alongside geospatial data, GIS incorporates attribute data, which provides supplementary information about each spatial feature (Rezaei et al.,2020). This attribute data might include characteristics such as the name, classification, or properties associated with a particular location or object (Kurowska et al., 2020). The spatial component of the data would represent the physical coordinates and boundaries of each store or shopping area, while the attribute data would contain details such as the name of the retailer, the type of products sold, and demographic information about the surrounding area. By combining these datasets, GIS enables users to perform spatial analyses, such as identifying optimal locations for new stores, evaluating market trends, or assessing the accessibility of retail services within different neighborhoods (Usmani et al., 2020).

Geographic Information Systems play a crucial role by facilitating the visualization and analysis of location-based data, thereby assisting organizations in making informed decisions (Pérez-delHoyo et al., 2020). The complexity of location data often requires detailed analysis to prevent costly mistakes, and effective GIS tools empower users to swiftly identify and improve decision-making regarding people, places, and relevant patterns. GIS allows for the utilization of geospatial analytics to develop insightful models for various location-centric scenarios, enabling organizations to visualize and analyze different outcomes to optimize decision-making processes (Fleischmann and van der Westhuizen, 2020). Given the growing volume of location data, modern GIS platforms must efficiently handle large files and maintain exceptional stability to support highly performant raster data processing. The integration of spatial and attribute data within GIS empowers users to gain valuable insights into complex geospatial phenomena, facilitating informed decision-making and problem-solving processes. This capability makes GIS an indispensable tool for addressing a wide range of challenges across various industries, from urban planning and environmental management to emergency response and public health. As technology continues to evolve, GIS will play an increasingly significant role in advancing our understanding of spatial relationships and promoting the development of geospatial intelligence (Ridha and Kamil, 2021).

FINDINGS AND DISCUSSION

Due to the significant impact of the digital divide, which underlies many of the challenges in implementing Geographic Information Systems (GIS), the practice of GIS within the education system has greatly reduced. This study reveals that many South African schools have reverted to traditional textbook teaching to circumvent the current challenges associated with GIS practice. The research indicates that numerous South African educators, much like their counterparts globally, struggle to teach GIS effectively in schools. There are substantial barriers preventing the integration of GIS practice into the curriculum. The study found that the challenges faced by South African educators in teaching GIS are like those encountered worldwide, contributing to the lack of GIS implementation at the school level. The next section discusses the utilization of geospatial technologies in South Africa’s rural education curricula and its impact on student learning outcomes.

The Utilization of Geospatial Technologies in South Africa’s Rural Education Curricula and its Impact on Student Learning Outcomes.

According to Mkhize (2023a), around 54% of South African children, equating to nearly 10 million, reside in rural households. These children face heightened vulnerability because services and resources in rural regions significantly trail those available in urban areas (Mkhize, 2023a). The notion of rural learning ecologies recognizes the unique circumstances and challenges encountered by rural students and seeks to enhance education within, between, and across rural schools, homes, and communities (Ma et al., 2023). In this research, a rural learning ecology is defined as a school setting with various components, including learners, teachers, staff, and parents, all working collaboratively for effective teaching and learning. Rural schools function as rural learning ecologies, where individuals survive through interaction and interdependence, adapting to changes over time (Their et al., 2021). The PBGIS (Paper-Based Geographic Information Systems) initiative targets schools without computer access. In South African schools, PBGIS was introduced as an alternative to traditional GIS due to the lack of computers (Mkhongi and Musakwa, 2020). Consequently, topographic and orthophoto maps are used to teach GIS, meaning that students learn about GIS rather than using GIS tools. The ESRI distributor in South Africa took the initiative to develop educational materials by collaborating with former geography teachers and other key individuals (Dube, 2020).). These materials address the full spectrum of GIS educational needs in the Department of Basic Education (DBE) and include three approaches: PBGIS, ArcExplorer, and ArcView, covering the basics of GIS theory. The GIS training program in Cape Town helped teachers assist poorer schools without computers, ensuring they were not left behind (Fleischmann & van der Westhuizen, 2020). The PBGIS initiative, overseen by ESRI, aims to bring GIS technology to under-resourced schools in South Africa that lack electricity or computers (Dube, 2020). According to Fleischmann and van der Westhuizen, (2020), The South African Department of Basic Education (DBE) faces the unique challenge of catering to diverse groups of rural learners. With twelve official languages, including South African Sign Language, there is a clear distinction between rural learners that are proficient in English and those who are not. Low English literacy rates often impede learners' understanding of abstract GIS terms, creating a fragmented academic community divided between disadvantaged and highly educated individuals. Economic disparities further complicate the situation, as many learners enjoy the benefits of private education while others lack basic GIS resources like computers. These factors significantly exacerbate the digital divide (Mkhongi and Musakwa, 2020), a situation evident even among teachers. When inadequate GIS literacy is combined with a lack of school community support, it leads to flawed GIS teaching experiences (Pérez-delHoyo et al., 2020). Regarding support, the CAPS document for GIS focuses on teaching and learning about GIS and emphasizes conceptual knowledge of general GIS concepts in Grade 10 (Lembani et al. 2020). It also allows for the teaching of geographic themes through GIS in Grades 11 and 12, with Grade 12 learners required to be proficient in geographical numeracy, GIS methods, and spatial statistics. Three different approaches to teaching GIS have been observed: teaching about GIS, teaching map skills through GIS, and teaching geographic or spatial concepts through GIS (Hintermann et al., (2020). However, ambiguity in the curriculum about GIS teaching may contribute to the delayed GIS practice in the FET Phase (Kraftl et al., 2022). Thus, it is essential to reconsider GIS integration methodology and develop learning teaching support materials (LTSM) and applications aligned and standardized with GIS curriculum requirements (Rushton, 2021).

Challenges in Utilization of Geospatial Information Systems (GSIS) in South African Rural Education Curricula

Geospatial Information Systems (GSIS) represent a powerful tool for enhancing educational outcomes through spatial analysis and visualization (Donitsa-Schmidt and Ramot, 2020). In rural South African education, GIS can potentially revolutionize teaching methods, making learning more interactive and practical. However, the implementation and utilization of GIS in these rural settings face numerous challenges. Addressing these challenges is critical to fully leveraging the benefits of GIS in education (Olatoye et al., 2022).

GSIS Infrastructure Deficiencies: As opined by Rees et al., (2020), one of the most fundamental challenges is the lack of adequate GSIS infrastructure in rural schools. Many rural schools in South Africa struggle with necessities such as reliable electricity and internet connectivity (Simasiku, 2020). GIS technologies require modern computers and stable internet connections to function effectively. Inadequate GSIS infrastructural elements means that even if GIS software were available, the schools would be unable to use it effectively. For instance, the computational power needed to run GIS software is significant, and without reliable electricity, maintaining computers and other necessary devices becomes nearly impossible. This infrastructure gap not only hinders the use of GIS but also limits students' and teachers' access to digital learning resources more broadly (Hintermann et al., 2020).).

Limited Access to GSIS Technology and Resources: Even when infrastructure is in place, rural schools often face a scarcity of technological resources. Many schools have limited budgets and cannot afford the necessary hardware, such as computers and GPS devices, or the software licenses required for GIS applications (Fleischmann and van der Westhuizen, 2020). Additionally, GIS education relies heavily on access to current spatial data, which can be expensive to acquire. There are free GIS software options available, but these also require significant training and technical support, which adds to the overall cost. Without adequate financial resources, schools struggle to provide students with the tools and materials needed to engage effectively with GIS technologies.

Teacher Training and Professional Development: According to Rushton, (2021), inadequacy of adequately trained teachers negatively affects the effective integration of GIS into the curriculum, because teachers are required to have a solid understanding of both the technology and its pedagogical applications (Rundel and Salemink, 2021). However, many teachers in rural areas lack this expertise due to insufficient professional development opportunities (Sharma et al., 2023). Training programs for teachers in GIS are not widely available, and those that do exist are often located in urban centers, making them inaccessible for rural educators (Mkhongi and Musakwa, 2020). Inadequate training means that even if schools could overcome GSIS infrastructure and resource limitations, they would still face difficulties in effectively integrating GIS into their curricula.

Curriculum Integration and Support: Integrating GIS into the rural education curriculum presents its own set of challenges. The current curriculum may not provide enough flexibility to incorporate GIS-related activities, or it may lack clear guidelines on how to do so (Donitsa-Schmidt and Ramot, 2020). Educational policymakers and curriculum developers need to recognize the value of GSIS and create frameworks that facilitate its inclusion. However, this requires a shift in educational priorities and significant investment in curriculum development (Roberts and Fuqua, 2021). Additionally, ongoing support and assessment are necessary to ensure that GSIS integration is effective and sustainable over time.

Socio-Economic Barriers: The socio-economic conditions of many rural communities also pose a challenge to the utilization of GSIS in education. High levels of poverty and unemployment mean that many students come from households without access to computers or the internet, limiting their ability to practice GIS skills outside of school (Pérez-delHoyo et al., 2020). Furthermore, these socio-economic barriers can affect students' attendance and engagement, as they might prioritize work or other responsibilities over school (Alea et al., 2020). Addressing these socio-economic issues is critical to ensuring that all students have equal opportunities to benefit from GIS education.

Language and Literacy Barriers: Language and literacy barriers can further complicate the implementation of GIS in rural schools (Lembani et al., 2020). Many GIS tools and resources are available primarily in English, which may not be the first language of many students and teachers in rural South Africa. This language barrier can make it difficult for both students and teachers to fully understand and utilize GIS technologies (Musakwa, 2017). Additionally, the technical jargon associated with GIS can be challenging for those with limited exposure to such terminology. Developing localized educational materials and providing support in multiple languages could help mitigate this issue (Pérez-delHoyo et al., 2020).

Sustainability and Maintenance: According to Their et al., (2021), ensuring the sustainability and maintenance of GIS programs in rural schools is another significant challenge. Once the initial setup is in place, ongoing maintenance of hardware, software updates, and technical support are essential to keep the systems running smoothly. Rural schools often lack the technical expertise required to handle these tasks, leading to reliance on external support, which can be costly and inconsistent. Establishing partnerships with local universities, NGOs, and government agencies could provide a more sustainable model for support and maintenance.

Cultural Relevance and Engagement: Making GIS education culturally relevant and engaging for students in rural areas is crucial (Rees et al., 2020). Educational content and examples used in GIS instruction should reflect the local context and address issues that are pertinent to the students' lives and communities. This relevance can increase student engagement and make learning more meaningful (Chisango et al., 2020). However, developing such context-specific materials requires collaboration with local communities and a deep understanding of the local culture and environment (Ridha and Kamil, 2021). The challenges to utilizing GIS in South African rural education curricula are multifaceted, encompassing infrastructural deficiencies, limited access to technology and resources, lack of teacher training, curriculum integration issues, socio-economic barriers, language and literacy barriers, sustainability concerns, and the need for cultural relevance (Their et al., 2021). Addressing these challenges requires a concerted effort from policymakers, educational authorities, teachers, and communities. Investment in infrastructure, professional development, and curriculum development is essential, along with ongoing support and collaboration with local and international partners (Rundel and Salemink, 2021). By overcoming these challenges, South Africa can unlock the full potential of GIS in rural education, providing students with valuable skills and knowledge that can contribute to their personal and community development.

CONCLUSION

Geospatial technologies have the potential to significantly transform rural education in South Africa by providing innovative solutions to longstanding educational challenges. Integrating Geographic Information Systems (GIS) and other geospatial tools into the curriculum can enhance the learning experience in rural schools, making abstract concepts more tangible and engaging. These technologies enable students to visualize and analyze spatial data, fostering critical thinking and problem-solving skills. For example, students can use GIS to study local environmental changes, plan community projects, and understand the geographical implications of socio-economic issues. Additionally, geospatial technologies can bridge the resource gap in rural areas by providing access to up-to-date information and digital learning materials. Despite challenges such as the digital divide and lack of resources, initiatives like the self-paced interactive GIS plug-and-play tutor application developed by North-West University demonstrate the feasibility of integrating these technologies into rural education. By equipping educators with the necessary tools and training, and addressing infrastructural barriers, geospatial technologies can play a pivotal role in enhancing educational outcomes and fostering sustainable development in South Africa's rural communities.

Teaching and learning GIS in South African rural schools faces several challenges. Firstly, regarding GIS content, concepts such as raster and vector data and data manipulation are most commonly taught in high schools, with more complex topics introduced progressively from grades 10 to 12. Secondly, challenges such as insufficient ICT support and inadequate teaching time highlight gaps in integrating GIS into geography curricula. Thirdly, concerning educators' proficiency, most GIS teachers possess relevant qualifications, indicating their competency. However, data manipulation is seen as the most difficult aspect, and few students consider GIS as a career option. Despite these challenges, GIS education holds significant promise for enhancing spatial thinking and improving geography performance. The integration of GIS into geography is envisioned as a transformative strategy for teaching, learning, and understanding spatial features. However, barriers such as financial constraints, time limitations, and disparities in teaching resources between private and government schools hinder the full potential of GIS education. The unstable geography pass rates in South Africa further underscore the need for consistent and equitable resources across all schools. Future research should expand to include multiple regions and schools within South Africa and other African countries to provide a more holistic understanding of the state of GIS education in high schools and help identify strategies to overcome existing challenges and leverage opportunities for improvement.

This study found that insufficient teacher training and a lack of resources necessary for GIS implementation present significant challenges for geography teachers in rural areas. To address these issues, it recommends that the Department of Basic Education (DBE), in partnership with universities, provide formal training for teachers and ensure that all schools have the necessary resources for effective GIS instruction. These training sessions could be extended workshops specifically focused on implementing GIS in schools, with DBE allocating funds for the required resources. Workshops organized by the DBE to support GIS implementation should include strategies to simplify complex GIS concepts for rural learners. Additionally, the study identified a shortage of adequate teaching time for GIS instruction. Therefore, the DBE should support geography teachers by reviewing the time allocated in the Annual Teaching Plan (ATP) for teaching GIS. Moreover, workshops facilitated by the DBE should help teachers develop strategies for effectively teaching GIS concepts. Furthermore, GIS examiners should conduct workshops to guide teachers on instructional approaches that align with examination question formats.

A targeted approach to investigating the integration of geospatial technologies in South Africa's rural education involves several strategic steps aimed at understanding and addressing the unique challenges and opportunities within these communities. This comprehensive, multi-faceted research plan includes stakeholder engagement, pilot projects, and iterative feedback mechanisms. Engaging key stakeholders, such as local educators, school administrators, community leaders, parents, government and educational authorities, and technology providers, is crucial to understand needs, gain support, and secure resources. Conducting thorough needs assessments and baseline studies helps identify specific challenges and requirements, such as infrastructure availability, skill levels, and curriculum gaps. Implementing pilot projects in a diverse range of rural schools provides valuable insights and practical experience, supported by comprehensive training for teachers and adequate resource allocation. Continuous feedback and evaluation, through regular monitoring and impact assessment, are essential for refining and scaling up integration efforts. Developing strategies for scalability and sustainability, including identifying successful pilot elements, exploring sustainable funding options, and building local capacity, ensures long-term success. Advocating for supportive policies and frameworks aligns the integration with national education goals and raises awareness among policymakers and the public. This collaborative approach can create a sustainable and scalable model for integrating geospatial technologies, enhancing educational outcomes, promoting digital literacy, and empowering rural communities with essential skills and knowledge for the digital age.

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