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Exploring Untapped GIS Application Possibilities for the Integration of Environment-Inclined Pedagogy in Geography Education: A South African Case Study

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ABSTRACT

The ubiquity of perennially evolving environmental challenges threatening the sustainability of the biophysical environment, the lifeblood of Planet Earth, require ceaseless innovative approaches to offset their calamitously impact. Over the years, environmental education (EE) has been useful in empowering learners, globally, with strategies to effectively address environmental issues. Geography is one of the school subjects that accommodate the infusion of EE in pedagogy. Significantly, the Geographical Information Systems (GIS) is one of the tools that can be used meaningfully to enable environment-inclined pedagogy in geography education. This interpretivist-qualitative study evaluates the application of GIS in the teaching of Grades 10 to 12 geography curriculum in South Africa and its potential for supporting the integration of EE in the subject. The content analysis of the Curriculum and Assessment Policy Statement (CAPS) that guides pedagogy in Grades 10 to 12 and Grade 12 November 2024 geography examination papers was used as the only research strategy while the inductive and deductive modes of reasoning aided the process of document content analysis. The findings of the study suggest that CAPS contains various themes that can be used to infuse EE using GIS in geography education. However, despite its usefulness and potential enabler of environment-inclined pedagogy in geography pedagogy, GIS is not meaningfully accommodated in geography education. The study recommends an expansion of the GIS content in the Grade 10 to 12 geography curriculum, provision of guidance to teachers on how to infuse EE using GIS and scaling up of GIS tools South African schools.

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1. Introduction

Over the years, environmental challenges have become pervasive global phenomena that are difficult to ignore. The world is plagued by a myriad of major environmental issues. Hardly a day goes by without an environmental catastrophe being reported in one or the other part of the world (Duchaeva and Magomadov, 2023; Shcheblyakov, et al. 2019). These environmental issues include, among other things, climate change, the depletion of the ozone layer, reduction in biodiversity, pollution and etcetera. Accordingly, the call for the integration of environment-inclined education through the introduction of innovative, practical, and solution-based approaches that are geared towards ameliorating ceaselessly unabating environmental challenges in pedagogy has become more relevant every day (Jickling, 2017).

Environment-inclined pedagogy gained approval largely because of the declaration made by the United Nations Conference on Human Environment held in Stockholm in 1972, which instigated the application of environmental education (EE) as a viable vehicle to address environmental issues globally. Its traction was consolidated by the first intergovernmental conference on environmental education held in Tbilisi, Georgia (USSR) in 1977. Recently, through its Sustainable Development Goals (SDGs)-driven 2030 Agenda, the United Nations (2015), particularly SDG 4, which emphasizes the provision of quality education to all people, emphasizes the role of education in ameliorating the scourge of environmental challenges. Therefore, with good reason, scholars continue to advocate for the advancement of innovative learning experiences that foster environmental sustainability, including exposure to e-learning environments (Mónus and Lechner, 2017).

The effective implementation of environment-inclined pedagogy is possible by using a multidisciplinary approach to pedagogy (Tete, Idiong and Nseabasi, 2023). Within the realm of geography education, geographic information systems (GIS) are a multidisciplinary tool with the potential to facilitate the infusion of EE in

geography pedagogy. The multidisciplinary nature of GIS is discernible from its propensity to enable the users to apply it as a resources and science tool to draw applications and approaches from a myriad of disciplines such as computer science, mathematics, geological sciences, remote sensing and etcetera (Kumar, Devi, and Deshmukh, 2014; Ramaprasad and Narayanan, 2019). Accordingly, it is not surprising that, in recent decades, the use of GIS has been gaining traction in school education, especially in high school education (Akinyemi, 2016; Fleischmann and Van der Westhuizen, 2020; Kanickaraj, 2021).

In South Africa, the country where the current study was conducted, GIS was introduced as part of Geography Education in Grades 10 to 12 from 2006 to 2008. However, its focus has been very narrow hence it forms a very small part of map work and thus constitutes only 5% of the examination. Notably, as directed by the Geography Grade 10-12 Curriculum and Assessment Policy Statement (CAPS), the document that guides pedagogy in South African classrooms, the GIS pedagogy in the realm of geography largely centres around, the definition of concepts, minimal theoretical learning about remote sensing, vector and raster data, spatial and attribute data, spatial and spectral resolution, data standardisation, data sharing, data security and data manipulation (Department of Basic Education, 2011; Hlatywayo and Manik, 2022).

Significantly, the theoretical learning of and limited attention given to GIS inadvertently precludes pedagogical focus that amplifies the applicability of GIS as a science and tool in the infusion of environment-inclined pedagogy in geography education in Grade 10-12 classrooms. Therefore, the current authors contend that this limitation enervates the potential and inherent capability of GIS, in the eyes of both teachers and learners, as a meaningful tool that enables society to address environmental challenges. Thus, it is essential to circumvent this shortcoming by amplifying the usefulness of GIS in the advancement of environment-inclined pedagogy, particularly its applicability in addressing environmental issues.

Accordingly, the purpose of this paper is to tease out from the Grade 10-12 Geography CAPS document some pertinent themes 'imbued' with environmental challenges and, briefly demonstrate how GIS could be applied to advance environment-inclined pedagogy in the Geography Education. This is essential because literature from other parts of the world indicates that GIS can be used effectively as a tool to enhance teaching and learning in geography. However, despite the growing global recognition of GIS as an invaluable vehicle for EE integration in geography education, there is a notable absence of systematic research identifying and mapping specific topics within the South African secondary school geography curriculum that lends itself to GIS-based integration for the effective infusion of EE. Therefore, it is the view of current researchers that this study is vital as it serves to contribute towards sealing this research gap. Significantly, this could be considered an essential effort to equip citizens in the quest to ameliorate environmental delimitation and blight through pedagogical innovation. Thus, this study seeks to answer the following question: Which topics could be integrated through GIS to facilitate environment-inclined pedagogy in Grade 10-12 Geography Education curriculum in South Africa?

2. Method

This section discusses the following aspects, respectively: research technique and paradigm, theoretical framework and data generation and analysis procedures pursued in the current study.

2.1. Research technique and paradigm

In this study, the researchers used a qualitative research strategy with interpretivism as the undergirding paradigm. The qualitative research approach was deemed appropriate in this study because it enables the researcher to explore an under-researched phenomenon, as is the case with this inquiry, and provides deeper insights for future research. Likewise, interpretivism was considered pertinent in that it makes provision for the use of "socially constructed multiple realities" (Rehman and Alharthi, 2016) in qualitative research. Accordingly, when used in tandem, qualitative research and interpretivism accommodate intuition, beliefs, subjective perspectives, and the wealth of experience of the researcher as the 'knower' (Anderson, 2019; Kivunja and Kuyini, 2017; Rehman and Alharthi, 2016). In the context of this study, the advantages of using qualitative research and the interpretivist paradigm empowered the researchers as 'the knowers' in the fields of Geography Education and Environmental and Sustainability Education the latitude to subjectively tap into their personal experiences to meaningfully address the question that prompted the current study.

2.2. Theoretical framework

To elucidate the succinct explication of the phenomena under discussion and thereby meaningfully respond to the research question guiding the inquiry, the study draws its theoretical undergirds from more than one perspective. Luft et al. (2022) reported that the use of more than one framework or perspective in a study enhanced the conceptual understanding and dissection of intricacies entailed in the phenomenon under investigation. Accordingly, Bernstein's (2003) pedagogical recontextualization principle, domain analysis

(Casimir, Tobi and Tamás, 2022; Dursun, 2023), Lucas's (1972) long-standing triadic approach to EE-pedagogy, and deductive and inductive (Fife and Gossner, 2024) modes of inference guided this inquiry.

Bernstein's (2003) tenet of recontextualization is germane to this inquiry in that it empowers the researcher, as the 'knower,' based on experience in (a) specific field(s) to, inter alia, determine the concepts that fulfil the needs for application in contexts that enable the inquirer or scholar to apply them for pertinent purposes. The application of domain analysis complements recontextualisation in that it is useful in enabling the researcher to define the constructs or concepts and categorize them to specific sets or subsets as determined by the needs of the 'knower.' Lucas's (1972) triadic approach to EE enables environment-inclined pedagogy, namely learning *about*, *in* and *for* the environment. Therefore, this is relevant to this study. In a nutshell, the triadic approach entails learning *about* the environment (the focus is on the advancement of theoretical awareness and knowledge of environmental issues), learning *in* the environment (this entails the exposure of learners to practical learning beyond the classroom walls in the real environment where the various senses are stimulated and used, including the physical manipulation of the environment), and learning *for* the environment (this form of learning is often equated to education for sustainable development, and the focus is on environmental activism where the learners are encouraged and guided to take action to sustain the wellness of and save the environment). Likewise, the deductive and inductive modes of inference were deemed useful when used simultaneously, in a complementary way, to enable inquirers to holistically explore, dispute, or approve the appropriateness (Dursun, 2023; Fife and Gossner, 2024) of themes for classification into domains determined for the purposes of the study.

2.3. Data generation and analysis

In this study, no human beings were interviewed, observed, or consulted as participants. Accordingly, inquirers used document content analysis as the sole data collection strategy. The main source document used for this purpose is the *Curriculum and Assessment Policy Statement* (CAPS) compiled by the Department of Basic Education (DBE) to guide geography pedagogy in grades 10 to 12 in South African public schools. This document is used by most private schools. The CAPS document covers all the themes covered by MUST be covered during the academic year in Grades 10 to 12.

The researchers meticulously scrutinized the topics that were covered more than once. Furthermore, they sourced and read, pedantically, the Grade 12 Geography Examination Question papers, written in November 2024. The choice of grade 12 was motivated by the fact that this is the school exit grade, and it receives a lot of attention from both the DBE and the public. The researchers believed that the examination and analysis of the question papers would provide an idea regarding the coverage of GIS in the examination. In addition, the researchers sourced and went through the Diagnostic Report compiled by the DBE, which reflects the Grade 12 November 2024, examination results.

The reading of the CAPS document was complemented by content analysis to, inter alia, determine the skills and knowledge integrated in the advancement of environment-inclined pedagogy and the use or potential use of GIS in the integration of EE in respective topics.

The theoretical framework explained in the preceding section was helpful in identifying pertinent themes that could be used to infuse EE and in determining the (potential) use of GIS in the process. Accordingly, the concurrent use of inductive and deductive modes of reasoning enabled the researchers to use "relevant constructs that have been examined previously in the literature" (Fife and Gossner, 2024) to determine the relevance of a theme or subtheme and its worthiness of inclusion in the study. For example, based on the wealth of literature on climate and climate change education (Boakye, 2015; Monroe, et al. 2017; Tolppanen, et al. 2020) which deals extensively with global warming as an aspect of heating of The Atmosphere, the researchers deemed it appropriate to include the topic "The Atmosphere" that is taught as part of the Grade 10 Geography Education curriculum, in this study. Likewise, the collective experience(s) of the current researchers enabled them to deductively infer that the concept of *the atmosphere* and related subthemes can be recontextualized and expanded beyond the suggestions entailed in the Geography Grade 10-12 CAPS document to integrate EE by covering learning *about*, *in* and *for* the environment and that GIS could be used (e.g., the study of local and distant environments through remote sensing) to facilitate pedagogical processes. This approach was used throughout the content analysis of the CAPS document, and ultimately, the researchers were able to identify the themes relevant to the study, as outlined in Table 1 in the Results and Discussion section.

2.4. Trustworthiness

Trustworthiness is a significant aspect of an inquiry. Significantly, in document content analysis, trustworthiness can be very challenging, especially when considering the dearth of guidelines on how the process must be ensured. In this study, the researchers were guided by Potter and Levine–Donnerstein's (1999)

suggestion that in content analysis researchers must follow the framework(s) that guide their study throughout the data collection and analysis process. Accordingly, in this study the researchers adhered to this suggestion.

Furthermore, the researchers considered and applied the recommendations by Elo, et al. (2014) who suggest that in content analysis involving more than one researcher, "one researcher is responsible for the analysis and others carefully follow-up on the whole analysis process and categorization. All the researchers should subsequently get together and discuss any divergent opinions concerning the categorization" (p. 5). Therefore, in this study, this suggestion was followed, and the roles of teasing out topics, analyzing the contents, categorizing, and following up on the activity done by the other researcher were carried out interchangeably between the two researchers to ensure trustworthiness. Furthermore, the researchers engaged in ongoing discussions to ensure that they were on the same page regarding the processes undertaken in the study. Upon concluding the process, a colleague with expertise in qualitative research and EE was requested to review the document and provide an input/opinion on the trustworthiness of the analysis.

3. Results and discussion

This section focuses on the presentation and discussion of the results emanating from the content analysis of the Geography Grade 10-12 CAPS document used to guide pedagogical processes in South African school settings. For ease of reference and comprehension by the reader, the results are presented in tabular form in Table 1. The table reflects selected themes gleaned from the Geography Grade 10-12 CAPS document. Owing to the limitations imposed by journal requirements, only a few relevant topics are presented in this section.

The first column of Table 1 indicates the respective grades (10–12) from which certain themes, among those prescribed for teaching and learning, could be used for the infusion of EE in Geography Education. The second column denotes selected themes (and subthemes where necessary) that could recontextualised to infuse EE in Geography pedagogy, the third column illustrates whether Lucas's (1972) triadic approach to EE could be applied while the fourth column illustrates the feasibility of using GIS in enabling environment-inclined pedagogy in the teaching of specific topic.

For example, Table 1, indicates that in the prescribed Geography Grade 10 curriculum, the theme on "The Atmosphere" together with apposite accompanying subthemes can be fashioned to enable the integration of EE in Geography pedagogy. Furthermore, climate change as an issue of environmental concern can be integrated by applying the notions of learning *about*, *in* and *for* the environment to advance theoretical knowledge *about*, study the impact of climate change *in* the environment, and participate in activism *for* the mitigation of current and future impacts of climate change on the environment. Additionally, numerous other issues of environmental concern (e.g., drought, desertification, and spreading of disease) that could be infused when handling the theme on the atmosphere are highlighted. Significantly, the table also underscores some of the strategies that could be used to enable EE infusion using GIS when teaching about the atmosphere in Geography Education. For instance, remote sensing is highlighted as a tool or strategy that can be used to remotely sense, record, and ultimately enable the mapping of the areas that could be affected by and the (potential) impact of climate change in specific local or distant geographical areas. Additionally, GIS can be used to assist in devising mitigation strategies to circumvent the potential effects of climate change.

It is the view of the current researchers that, for the purposes of this discussion, the preceding points adequately capture the essence of the various possibilities that exist with respect to how Geography Education could enable the infusion of EE, partly, with the aid of GIS. Accordingly, the following table indicates some of the topics that could be used, pertinently, to address the question that drives this study.

Table 1. Some topics that could enable EE integration through GIS in South African schools: Geography Education Grade 10-12

Grade	Topic	Triadic approach to EE	Potential role of GIS
10	The atmosphere • The composition and structure of the atmosphere • Heating of the atmosphere • Moisture in the atmosphere	Possibilities exist for the application of learning *about*, *in* and *for* the environment. For example, topical issues of environmental concern such as the depletion of the ozone layer, the causes, impact and mitigation of climate change could be integrated in this topic. Other environmental challenges that could be infused include • Droughts,	GIS could be applied in various ways. For example, • Remote sensing and mapping of some negative effects of greenhouse gases. • Juxtaposing the local and distant environments • Examining actions used to mitigate climate change in local and distant environments

Grade	Topic	Triadic approach to EE	Potential role of GIS
		• Desertification, • Spreading of diseases, • Flooding, • Poverty and • Lowering/rising of sea levels	• Collocating local and distant environments and pre-empting potential future settings/situations
11	Resources and Sustainability • Using resources • Soil and soil erosion • Conventional energy sources • Non-conventional energy sources • Energy management in South Africa	Education *about*, *in* and *for* the environment can be assimilated into topics of environmental concern such as soil erosion, its causes, evidence, effects and management strategies. It could also be integrated in environmental issues such as: • Coal mining • Thermal power stations • Environmental despoliation • Pollution • Acid rain	• GIS offers techniques that can monitor environmental issues such as soil erosion, exploitation of resources, the impacts of conventional energy and non-conventional energy on the environment. • Through remote sensing aerial photographs and satellite imagery are used to gather data in inaccessible, moreover, before and after imagery can help to assess how the environment changed after environmental issues.
12	Geomorphology • Catchment and River management	The potential for applying education *about, in* and *for* the environment exists in environmental issues such as poor river management. It also accommodates studies about the impact of people on drainage basins and catchment areas such as: • River pollution (e.g. eutrophication) • Overgrazing • Deforestation • Human settlement	GIS presents a superior technology for monitoring catchment areas conditions. Through GIS buffering can be applied as a strategy to manage drainage basins.

As illustrated in the above table and the preceding discussion, it should be evident that numerous possibilities exist on how the Geography Grade 10-12 CAPS document that guides pedagogy in South African schools could be used to enable the integration of environmental challenges using GIS in pedagogy. The findings suggest that in each grade selected for this study, numerous topics can be used to integrate EE through the longstanding and undisputed triadic approach to EE, as postulated by Lucas (1972), regarding learning *about*, *in*, and *for* the environment. Similarly, GIS stands out as a useful strategy and tool that can be used to aid this integration.

For example, to integrate the global topical issue of environmental concern, climate change, in the teaching of the topic "The Atmosphere" prescribed for the Grade 10 Geography Education curriculum, learning *about*, *in* and *for* the environment can be enabled. Significantly, for the purposes of this study, which seeks to probe the usefulness of GIS in the process, evidence from both this study (as already illustrated) and the literature suggests that GIS can be used and has been used to infuse climate change as an aspect of pedagogical process in education. Various scholars support the assertions made in this study regarding the applicability of GIS in the infusion of EE. For instance, Wang (2023) highlights that remote sensing is useful for monitoring the impact of climate change in enabling natural hazards such as flooding at local, regional, and local levels. This assertion echoes the findings by Twumasi et al. (2017), who conducted a study in various parts of West and Southern Africa. GIS as a geo-spatial technological tool also enables scientists to study the concentration of climate change-inducing gases and their (potential) impact on the environment such as their contribution to the spreading of vector diseases, like malaria, in various geographical regions (Hummel, 2022; Kimuyu, 2021). This aids in mapping the (potential) impact of these factors in various geographical regions and facilitates mitigation strategies to circumvent the effect on humanity and the broader environment. Undoubtedly, the preceding arguments illustrate the usefulness of GIS in the integration of environment-inclined pedagogy into Geography Education in the school curriculum.

Likewise, the Grade 11 geography curriculum provides opportunities for the use of GIS to advance environmental learning. This could be done, inter alia, through the teaching of the topic "Resources and Sustainability". This theme provides for the infusion of environmentally inclined subthemes that can be meaningfully integrated through GIS. For example, environmental issues such as soil erosion, pollution, and acid rain can be monitored from small-scale to large-scale as data can be captured, stored, manipulated, analyzed, and displayed to show past and present environmental crises, and predictions of likely future events that might have negative environmental effects are all possible through the application of GIS. Accordingly, this could enable planners to circumvent the current and potential future impacts of these environmental crises and implement mitigation measures to benefit the holistic environment.

For the purposes of this discussion, one more example is extracted from the Grade 12 curriculum. There is a myriad of possible applications of GIS in enabling the infusion of EE within the broader theme of "Geomorphology." The potential for applying education *about*, *in*, and *for* the environment exists in environmental issues, such as poor river management. It also accommodates studies of the impact of people on drainage basins and catchment areas. For example, within the concept of geomorphology, GIS can be used to enable a meaningful and practical understanding of processes entailed in studying river systems, including the pollution of streams (e.g., through eutrophication), the impact of deforestation, overgrazing, and the clearing of the land for residential purposes, and industrialization contribute to river pollution. Accordingly, GIS is a superior technology for monitoring catchment areas. GIS buffering can be applied as a strategy for managing drainage basins.

Accordingly, based on the preceding points, GIS can be leveraged to enable geospatial analysis, mapping, and modelling of the current and predict the potential future status of drainage basin systems, including the extent to which stream water is polluted and the potential implications for the holistic environment (Bavishi and Shekhar, 2025, Pradhan, et al. 2025). Accordingly, the use of GIS in this manner in geography education would enable learners to gain a better understanding of environmental challenges, such as pollution, impacting the environment, and could be guided pedagogically to critically reflect on possible solutions to those challenges, including fostering learner awareness on the importance of managing water resources and ensuring their availability for future needs. The use of GIS in this manner serves to contribute not only to SDG 4 but also to the realization of SDG 6, which is about ensuring sustainable management and provision of sanitation to global citizens (United Nations, 2015).

As indicated in the data generation and analysis section, apart from the data indicated in Table 1, the current researchers examined the Geography Grade 12 end-of-year examination papers 1 and 2 to determine the extent and way in which GIS is accommodated in the school exiting grade. The current authors examined November 2024 Papers one and two because these were accessible on the DBE website. The focus was on the extent to which GIS was covered in the respective papers and whether the GIS component, if covered, had elements that were inclined toward EE.

Upon examining Paper 1, which comprised a total of 150 marks, the researchers found that only 8 marks were allocated to GIS. Of the eight marks, only four were allocated to questions with EE inclinations. The questions focused on buffering with two marks allocated to the definition of the concept of buffering, while the other two marks required candidates to explain how buffering would protect the quality of water in a specified river.

Similarly, in Paper 2, which also contained a total of 150 marks, eight marks were allocated to GIS. However, unlike Paper 1, none of the questions had anything to do with fostering EE. Furthermore, researchers sourced and read a diagnostic report (DBE, 2025). This report was compiled by the DBE with the purpose of analyzing learner performance in school exit examinations, with a focus on the strengths and weaknesses of the examination results, and to highlight possible underlying reasons for performance leanings (DBE, 2025). Based on these analyses, the DBE provided suggestions on how learner performance could be improved to increase the grade 12 pass rate in geography and other subjects.

In their report, they noted in respect of geography, that the "candidates continued to struggle with Geographical Skills and Techniques and Geographic Information Systems (GIS), which were examined in both question papers. Many candidates did not understand the terminology and the application thereof to answer questions on GIS" (DBE, 2025). Subsequently, they made recommendations on how to improve learner performance in the subject.

Notably, their recommendations do not specifically refer to GIS or the use of GIS in the integration of EE into pedagogy. For example, they write that "learners need to understand the importance of integrating their theory knowledge with Geographical Skills and Techniques....The frequent use of topographical maps and orthophoto maps as teaching aids in theory lessons will assist learners. Mapwork skills and interpretation exercises should be regularly practiced in all types of questions, for example, multiple-choice, map

calculations, map application and interpretation, and GIS" (DBE, 2025). Additionally, they suggested that "Geographic Information Systems must be taught in detail. Teachers must emphasize the significance and purpose of GIS concepts and how to apply them". Furthermore, they propose that "GIS concepts and application thereof need to be well taught and regularly practised. Use of both topographical and orthophoto maps is essential for this" (DBE, 2025).

Evidently, the reviewers did not emphasize the practical, frequent, and meaningful use of GIS. Significantly, they do not refer to the use of GIS for the integration of EE in geography to empower the learners to become stewards of pro-environmental actions and promotion of sustainability. Accordingly, it is the view of current researchers that if GIS is to me meaningful as a tool to advance geography pedagogy and, significantly, to empower learners with environmental awareness and knowledge and, thereby, contribute to the advancement of SDGs, then the South African DBE needs to turn things around and factor tangible recommendations into their geography subject improvement plans. Some of these recommendations have been highlighted in the conclusion of this study.

3.1. Summary of findings

The findings of this study reveal that numerous themes within the Geography Grade 10–12 CAPS documents, which guide geography education in South Africa, present invaluable opportunities for the integration of EE using GIS. Numerous themes were identified across the three grades, e.g., "The Atmosphere," "Resources and Sustainability," and "Geomorphology" as suitable for applying Lucas's (1972) triadic model of EE, viz., learning *about*, *in*, and *for* the environment. Accordingly, the paper demonstrates that through, for example, spatial analysis and visualization, GIS can be used to facilitate a deeper understanding of environmental issues, such as climate change, pollution, land degradation, and poor river basin management. Furthermore, it amplifies the invaluable role of GIS as an enabler of meaningful learning, inclined towards enhancing EE, in geography education in secondary school settings.

3.2 The novelty of the study and its contribution to geography education

This study contributes new context-specific knowledge to the field of geography pedagogy in South Africa by demonstrating how GIS can be systematically leveraged to enable the integration of EE in the teaching of geography in secondary schools. Furthermore, this study contributes to the knowledge gap discernible from the reviewed literature, which suggests that researchers from underdeveloped countries such as South Africa need to conduct more studies that seek to probe the applicability of GIS as a vehicle for meaningful infusion of EE in geography education. This assertion is premised on the observation, informed by the literature review, that studies with focus on the extent to which GIS is applied in secondary school geography education are conducted, largely, in developed countries and better-resourced educational systems, globally. Accordingly, this study highlights practical entry points for using GIS within the CAPS framework in the under-resourced South African context.

4. Conclusion

The global nature, evolution, and expansion of environmental challenges are palpable, and their negative impact cannot be denied. Continuous efforts are required to develop strategies that do not only seek to address current environmental challenges, but also to equip young people as future leaders and inheritors of Planet Earth, and the plethora of current and potential environmental challenges. This study highlights the significance and usefulness of GIS as a tool that can aid the infusion of EE in geography education. Notably, the study highlights a handful of themes that could be used to aid this process within the grade 10 to 12 South African schooling system. Furthermore, it underscores certain approaches that can be used to achieve this goal. Of concern, however, is that despite its demonstrable usefulness in the teaching of geography and potential in the meaningful integration of EE in geography pedagogy, GIS is barely accommodated in Grades 10 to 12 school curricula.

Accordingly, policymakers in the DBE need to review the preceding shortcomings. This could be done by, inter alia, increasing the content of GIS in geography education and providing guidance and training to teachers on how the GIS content could be repackaged and used to infuse EE in geography education. Additionally, based on its notable scanty inclusion and exclusive focus on the theoretical nature of GIS content in geography pedagogy, education authorities also need to turn this situation around. GIS content should be more practical and relevant to existing geographical realities, especially the environmental challenges that plague the biophysical world. Therefore, the DBE needs to provide schools with relevant and useful GIS tools to enable meaningful, practical, and relevant learning about geographical issues of local and global environmental

concerns. In doing so, they are likely to better prepare school learners to become empowered, environmentally aware, and knowledgeable environmental stewards with the necessary capacity to effectively address current environmental issues, predict potential challenges, and develop strategies to circumvent those challenges.

GIS stands out as a transformative tool for enhancing environmental learning within geography education, offering spatial perspectives that are crucial for understanding and responding to contemporary environmental challenges. By mapping and modelling real-world data, learners are empowered not only to acquire knowledge, but also to critically engage with their environments and contribute to sustainable solutions. This study affirms the pedagogical power of GIS in fostering both environmental literacy and action, contributing meaningfully to global education and sustainability goals such as SDGs 4 and 6 within the South African schooling context.

Arguably, this study has the potential to provide other researchers with ideas to conduct similar studies to contribute to this, ostensibly, under-researcher area. For this reason, the study recommends more research of a similar nature to be conducted both in South Africa and elsewhere. This could enable global scholars within the space of geography education and sustainability-oriented groups and individuals to learn from one another and share good practices. This is a major way to address the ever-threatening scourge of global environmental challenges.

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