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Teachers' Perceptions of Paper-Based GIS Implementation in The Rural Learning Ecology

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ABSTRACT

In South Africa, paper-based geographic information system (PBGIS) was introduced as a strategy to resolve the hindrances in schools without computers in implementing GIS. This study explores the geography teachers' perceptions of implementing PBGIS in a rural learning ecology. In this context, PBGIS is defined as teaching and learning of GIS utilising topographic and orthographic maps, while rural learning ecology refers to a school in a rural environment consistent with how learners learn in a particular context. The unified theory of acceptance and use of technology (UTAUT) constituted the theoretical framework used to understand the geography teachers' perceptions in this inquiry. Qualitative research methods, and semi-structured interviews were used to generate data to answer the research question. Two geography teachers from a rural learning ecology were purposively selected to participate in this study. The data generated from the field was then analysed thematically utilising a deductive and inductive approach. The findings showed the following: inadequate teacher training; teachers are unsure about the resources required for PBGIS; lack of teaching time; and the complexity of PBGIS concepts, and improper PBGIS examination setting. This study proposes that the Department of Basic Education (DBE), in association with universities, train teachers and provide resources; support teachers by reviewing the time allocated in the Annual Teaching Plan (ATP) for teaching PBGIS; engage teachers about ways to simplify PBGIS concepts when teaching; and guide teachers on the approaches that must be used when teaching PBGIS.

KEYWORDS

Paper-based geographic information system (PBGIS); geographic information system (GIS); rural learning ecology; geography

INTRODUCTION AND BACKGROUND

The potential positive impact of geographic information system (GIS) on geography instruction has led to a global movement to include it in school curricula (Fleischmann & van der Westhuizen, 2020). In South Africa, GIS was listed as a skill to be acquired in the National Curriculum Statement (NCS) in 2003. However, its actual inclusion in the curriculum was only phased in from 2006. In 2006, the Department of Basic Education (DBE) only introduced GIS as part of the grade 10 geography syllabus for the first time and it extended to grades 11 and 12 in 2007 and 2008. However, research conducted about the implementation of GIS in schools reveals that geography teachers are faced with the challenges of teaching GIS in the classroom (Fleischmann & van der Westhuizen, 2019; Scheepers, 2009). Among concerns, researchers note a lack of any theoretical grounding and practical experience in using GIS by geography teachers (Mkhongi and Musakwa, 2020; Zietsman, 2002). This is because teachers in South Africa lack professional development in teaching GIS (Fleming, 2015). This paper explores geography teachers’ perceptions of implementing PBGIS in a rural learning ecology.

Conceptualising Geographic Information System (GIS)

Most definitions of geographic information system (GIS) are geared in the context of information technology (IT); they refer to microcomputers, hardware, software, databases, database management systems, and digitising. Kholoshyn et al. (2021) and the Environmental Systems Research Institute (ESRI, 2008) define GIS as a computer-based system comprising a database and a set of tools for collecting (capturing), storing, checking, editing, retrieving, integrating, manipulating, transforming, analysing, and displaying geographically referenced data. Oda, Herman, and Hasan (2020) add that GIS is a container of maps in digital form, and a computerised tool for performing geographic data operations that are too tedious, expensive, or inaccurate if performed by hand.

It is apparent from these definitions that GIS transitions from being viewed as a computerised system to being defined as a general set of hardware and software tools used to analyse and model data, and to solve problems (Kerski et al., 2013; Klose, 2021). While perhaps suitable at the universities, these definitions are hardly appropriate at the introductory level or for schools where IT is currently unavailable (Alibrandi & Palmer-Moloney, 2001; Kholoshyn et al., 2021). These definitions are also perhaps too technical for poorly resourced learning ecologies in South Africa where GIS is taught utilising topographic maps and orthophoto maps.

Conceptualising a Rural Learning Ecology

According to Hlalele (2014), about 54% of South African children live in rural households, which is almost 10 million children. In South Africa, these children are made vulnerable because service providers and resources in rural areas lag far behind urban areas (Hlalele, 2014). The definition of rural learning ecologies acknowledges the context and conditions in which rural learners find themselves and seeks to reinforce learning within, between and across the rural school, home, and community (Hlalele, 2014). Hence, the rural learning ecology focuses on teaching and learning in rural schools. For this research, a school setting is regarded as a rural learning ecology with different components such as learners, teachers, working staff, and parents whose core responsibility is to work together for effective teaching and learning. The rural school is identifiable as a rural learning ecology because individuals survive through interactions and interdependence to adapt to changes that may occur over time.

PBGIS Implementation in Schools

The PBGIS topic targets schools with no computer access. PBGIS implementation in South African schools was introduced as an alternative to GIS due to the lack of computers (Breetzke et al., 2011). Therefore, South Africa uses topographic and orthophoto maps to teach and learn GIS in schools. This means that learners learn about GIS and not with the GIS tool. Therefore, the ESRI distributor in South Africa took the initiative to assist and approach former geography teachers and other key people to guide the development of educational material (Breetzke et al., 2011). Complete GIS materials were developed to address the full spectrum of GIS educational needs in the DBE. The new school materials include three separate approaches corresponding to the fundamental steps for learning GIS: namely, PBGIS, ArcExplorer, and ArcView.

This included fundamental training, covering the basics of GIS theory. At the beginning of the year, geography curriculum advisors countrywide were flown or driven to GIMS's Midrand offices to attend a GIS training course (Breetzke et al., 2011; Fleming & Evans, 2021). Approximately one hundred curriculum advisors attended the three-day training for three weeks. Day one saw the facility transformed into a training centre for schools with no GIS computer facilities. The geography curriculum advisors were given a simple GIS task to complete with the aid of maps (courtesy of the Department of Land Affairs), crayons, and tracing paper (Breetzke et al., 2011; Fleming, & Evans, 2021; Kerski et al., 2013; Mzuza & Van der Westhuizen, 2020). The task involved searching for the best location to evacuate residents in the event of a flood.

This PBGIS proved very important for teaching conceptual issues of GIS before moving to the computer. Fleischmann and van der Westhuizen (2020) point out that the GIS training programme held in Capetown in 2008 helped teachers learn how to help poorer schools without computers to do GIS. This made teachers happy because their schools would not be left behind. A PBGIS initiative, managed by ESRI South Africa (Pty) Ltd., envisages the introduction of GIS to resource-poor (without electricity and/or computers) schools in South Africa (Breetzke et al., 2011; Kerski et al., 2013; Fleischmann & Westhuizen, 2015; Fleischmann & van der Westhuizen, 2020).

THEORETICAL FRAMEWORK

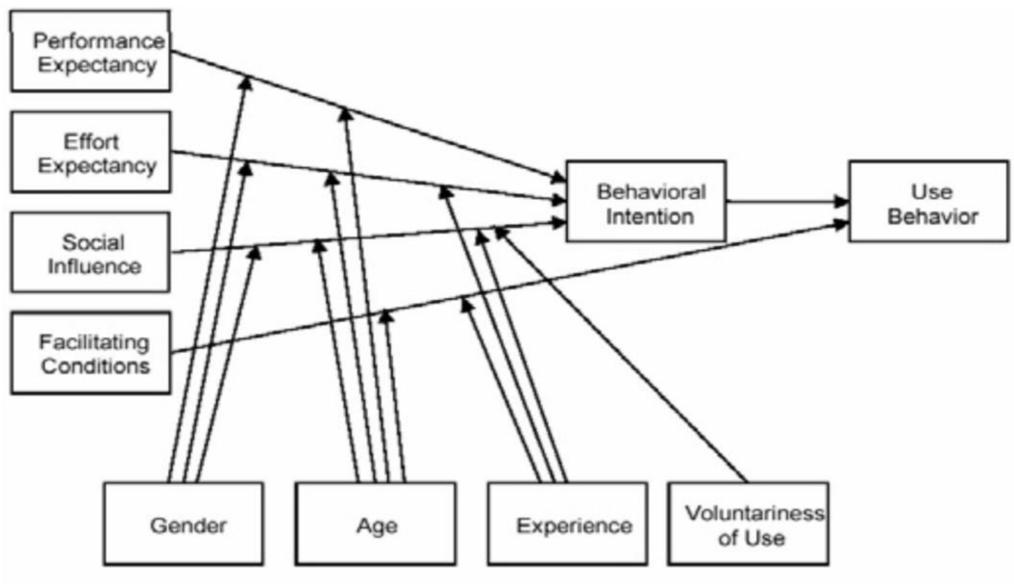
The study adopted the unified theory of acceptance and use of technology (UTAUT) as a theoretical framework. This model synthesised elements across eight well-known technology acceptance models: the theory of reasoned action (TRA), the technology acceptance model (TAM), the motivational model (MM), the theory of planned behaviour (TPB), the combined TAM and TPB, the model of PC utilisation (MPTU), the innovation diffusion theory (IDT) and the social cognitive theory (SCT) (Chiemeke & Evwiekpaefe, 2011; Liebenberg et al., 2018; Venkatesh et al. 2003). Combining technology acceptance models to formulate the UTAUT model was to achieve a unified view of user acceptance (Venkatesh et al., 2003). Thus, the UTAUT model is broad, robust, and powerful in information system (IS) adoption. The UTAUT model claims to be a valuable tool to assess the likelihood of acceptance of new technology within an organisation. It also helps to understand factors that drive acceptance of new technology so that appropriate features can be designed to facilitate user acceptance of new technology. The UTAUT model was chosen to understand a teacher's perception of implementing PBGIS in a rural learning ecology.

The UTAUT model presents four core determinants of intention and four moderators of key relationships. The four determinants of intention and usage are performance expectancy, effort expectancy, social influence, and facilitating conditions. The four moderating effects are age, gender, experience, and voluntariness of use. However, since the DBE instituted mandatory use of PBGIS, I could not include voluntariness of use as one of the moderating effects for this research. Therefore, I controlled for voluntariness of use in the UTAUT model.

The following diagram shows Venkatesh's model of the Unified Theory of Acceptance and Use of Technology.

Figure 1

The UTAUT model (Venkatesh et al., 2003, p. 447).



Factors of UTAUT

Facilitating conditions refer to the degree to which an individual believes that an organisational and technical infrastructure exists to support the use of the system (Gupta et al., 2008). Facilitating conditions as a determinant of intention in the acceptance and use of GIS was suitable for this research in understanding whether geography teachers are accepting and finding PBGIS useful due to the limited access to and availability of hardware and software, and electricity in many South African rural learning ecologies (Johansson, 2006). Performance expectancy can be seen as the degree to which an individual believes that using a system will help him/her attain gains in job performance and therefore enhance the quality of his/her work (Liebenberg et al., 2018; Mutlu & Der, 2017; Venkatesh et al., 2003). Performance expectancy is applicable to this study, and I was able to unfold whether geography teachers believe that PBGIS will enable them to deliver the curriculum content better to learners based on GIS, with good results.

Effort expectancy is defined as the degree of ease associated with the use of a certain system (Liebenberg et al., 2018). Effort expectancy is applicable to the study and might be related to learner performance because a teacher teaches to meet lesson outcomes. Therefore, the results can be judged through learner performance. So, according to the diagnostic reports, you might find that the teacher expects learners to perform well, yet they do not. Social influence is the degree to which an individual perceives that others believe it is important that she should use the new system (Mutlu & Der, 2017). Therefore, the social influence enabled me to reveal whether teachers influence one another in using PBGIS.

The Mediators of the UTAUT Model

Self-efficacy, anxiety, and attitude towards using technology are the mediators. This means they are not direct determinants of behavioural intention. According to Liebenberg et al. (2018) a mediator explains the nature of the relationship between the independent effect and the dependent effect. The independent effects are performance expectancy, effort expectancy, social influence, and facilitating conditions, while the dependent effects are gender, age, experience, and voluntariness of use (Venkatesh, 2003). A mediator implies that the independent effect influences the mediator effect, which influences the dependent effect. The mediators are applicable to this study. This is because I was able to investigate whether performance expectancy, effort expectancy, social influence, and facilitating conditions as independent effects influence self-efficacy, anxiety, and attitude as mediators in the implementation of PBGIS in rural learning ecologies. In turn, I was also able to explore whether the mediators influence gender, age, and experience as dependent effects.

Self-efficacy is defined by Bandura (1995) as a person's belief in their own ability to succeed in a specific situation or in accomplishing a task. Self-efficacy as a mediator towards using technology applies to this study. This is because self-efficacy as a mediator towards using technology enabled me to explore whether geography teachers believe in their abilities to implement PBGIS in rural learning ecologies. In turn, I could explore if geography teachers accept the use of PBGIS implementation in rural learning by understanding their abilities. This is because self-efficacy can play a major role in how geography teachers approach goals, tasks, and challenges of PBGIS in rural learning ecologies.

Anxiety is a sense of worry, nervousness, or unease about something with an uncertain outcome (Oxford English Dictionary, 2014). Anxiety as a mediator towards using technology is applicable to this study because it enables the researcher to investigate whether geography teachers have a sense of worry and nervousness because of being uncertain about implementing PBGIS in rural learning ecologies. In turn, it is then possible to explore whether geography teachers accept PBGIS implementation in the rural learning ecologies. The performance expectancy, effort expectancy, social influence, and facilitating conditions as independent effects may influence a teacher's sense of worry and nervousness towards implementing PBGIS. In turn, anxiety can influence dependent effects such as age, gender, and experience (Venkatesh et al., 2003). For example, older, female, and inexperienced geography teachers may have a sense of worry, nervousness, and unease about the use of PBGIS in rural learning ecologies or vice versa.

Attitude towards using technology can be seen as a person's overall affective reaction to using a system (Venkatesh et al., 2003). Attitude as a mediator towards using technology is applicable to this study since I explored the geography teachers' reactions towards implementing PBGIS in rural learning ecologies. In turn, geography teachers' perceptions enable the exploration of whether they accept PBGIS implementation in rural learning ecologies. Performance expectancy, effort expectancy, social influence, and facilitating conditions as independent effects may influence teachers' perceptions towards implementing of PBGIS in rural learning ecologies. In turn, attitude can influence dependent effects such as age, gender, and experience (Venkatesh et al., 2003).

Moderating Effects of the UTAUT Model

The moderating effect of age relates to the age of particular users (Muhsin & Nurkhin, 2016). The moderating effect of age in the context of a general adoption environment is applicable to the study because I was able to investigate whether age influences the acceptance and implementation of PBGIS in rural learning ecologies. For this study, I considered age as a moderating effect on the adoption environment of PBGIS in South Africa.

The moderating effect of gender relates to the sexual categories of the technology users, which is either male or female (Muhsin & Nurkhin, 2016). Gender is applicable to the study. Hence, gender was considered to reveal whether female teachers receive PBGIS in rural learning ecologies differently from male geography teachers. The moderating effect of experience is applicable to the study. This is suitable for the study since geography teachers' experiences in teaching and learning may play a role in the acceptance and use of PBGIS.

Behavioural Intention

Behavioural intention refers to an individual's choice to use technologies in the future, whether he or she is currently using it. According to Ajzen (1991), intentions are assumed to capture the motivational factors that influence behaviour; they are indications of how hard people are willing to try, and how much effort they are planning to exert, to perform the behaviour. Behavioural intention is applicable to this study. I was able to investigate the effort geography teachers exert in the implementation of PBGIS, and further explore whether these teachers are willing to try hard to use PBGIS. According to Venkatesh (2003), the general rule is that the stronger the intention is to engage in a behaviour, the more likely its performance should be. Thus, if geography teachers are more willing to implement PBGIS in rural learning ecologies, their effort may ensure the future use of PBGIS in their schools.

METHODOLOGY

This study is located within the interpretive paradigm. The main assumption of this paradigm is that reality is socially constructed and that there are as many intangible realities that people construct (Bertram & Christiansen, 2014; Thanh & Thanh, 2015). As an interpretive researcher, I explored how teachers perceive and implement PBGIS in a rural learning ecology. In this way, different interpretations from participants were obtained because their realities were not the same. Thus, I was able to engage in geography teachers' experiences subjectively to understand their journeys.

This study adopted a broad category of qualitative research design. There are several types of qualitative research designs, namely: grounded theory, ethnographic, narrative research, historical, case studies, and phenomenology (Allan, 2020; Silverman, 2020). I adopted a qualitative research design to explore geography teachers' perceptions of PBGIS implementation in a rural learning ecology. This study adopted a case study research methodology because the case study research methodology systematically captured the reality of the teachers' lived experiences of implementing PBGIS in a rural learning ecology.

This study adopts non-probability sampling in which the chance or probability of each unit being selected is not known or confirmed (Rahi, 2017). This means that participants in the non-probability sample are not given an equal chance to participate; instead, they are selected based on their accessibility or by the purpose and personal judgement of the researcher. Therefore, by utilising non-probability sampling, I was enabled to be purposive and make personal judgements in selecting participants. This study adopted convenience sampling, which defines a non-probability or non-random data generation process from a population that meets certain criteria, such as geographic proximity, ease of access, availability at a given time, or willingness to participate. Thus, convenience sampling enabled me to research two schools in which geography is taught as one of the subjects in the Further Education and Training phase (FET).

This study adopts a purposive sampling approach since this approach is representative, and non-random, and participants selected have the needed information. I, therefore, selected geography teachers from rural learning ecologies because they are the ones who teach GIS in resource-poor classrooms. Therefore, it implies that the selected participants would have the needed information. The participants of this research study were two geography teachers from two poorly resourced rural schools who were purposively chosen. Both participants were males aged thirty and thirty-two. The participant aged thirty had nine years teaching experience and the other participant aged thirty-two had eight years teaching experience. Purposive sampling targets knowledgeable people with in-depth knowledge about certain issues like professional roles, power, expertise, or experience (Rahi, 2017). As a researcher, I chose experienced teachers to gain in-depth knowledge regarding teachers' perceptions about teaching PBGIS in a rural school. Etikan, Musa, and Alkassim (2016) add that the purposive sampling technique, also called judgment sampling, is the deliberate choice of a participant due to the qualities the participant possesses.

This study adopted a semi-structured interview as the data generation method. The open-ended questions enabled me to ask follow-up why or how questions. The dialogue meandered around the topic on the agenda rather than adhering slavishly to verbatim questions as is often the case in a standardised survey (Adams & Lawrence, 2018). The semi-structured interviews enabled me to word questions instinctively and develop a conversational style during the interview that focused on the topic. Adams and Lawrence (2018) point out that about one hour is considered a reasonable maximum length for semi-structured interviews to minimise fatigue for both the interviewer and respondent. For this study, semi-structured interviews that were conducted lasted for about thirty minutes each, one interview per teacher and we only met once for the interview. This minimised the chances of mental tiredness which might have disrupted the data collection process.

To generate data in this study, individual semi-structured in-depth interviews were conducted to set questions for the interviewee, providing room for ideas development. The semi-structured interview, as stated earlier, often asks open-ended questions and probes the responses (Magaldi & Berler, 2020). I asked the teachers further questions on PBGIS, some of which may have emanated from the discussions that occurred during the interviews. During the interview, participants were audio-recorded to obtain every piece of information discussed the implementation of PBGIS in a rural learning ecology. The reason for the audio-recording was explained explicitly to the participants.

This study adopted the thematic data analysis approach, which enabled me to see and make sense of the collective or shared meanings and experiences indicated by the data set. The semi-structured interview data were analysed utilising a combination of deductive and inductive thematic analysis approaches. The study adopted Clarke and Braun's (2014) thematic analysis is a six-phase process. The six-phase process is as follows: familiarisation, generating initial codes, searching for themes, reviewing potential themes, defining, and naming themes, and producing the report (Clarke & Braun, 2014; Terry, 2016). For the study, all phases were adopted to tell the rich and complex story of how geography teachers perceive and implement PBGIS in rural learning ecologies.

Ethical considerations are important in qualitative research as this approach often intrudes on participant's lives (Flick, 2009). Principles of research ethics ask that researchers avoid harming participants involved in the process by respecting and considering their needs and interests (Khan, 2014). Research permission was requested from the DBE, school principals, and research participants to interview geography teachers in two selected schools within the Province of KwaZulu-Natal. I also went through the UKZN ethics application to avoid harm to participants. To avoid revealing the individuals' identities, the confidentiality of the participants was guaranteed by using pseudonyms for the schools and participants. According to Bertram and Christiansen (2014), this is called nonmaleficence, where harm is avoided to those involved in the research. I motivated participants to share their past experiences on implementing PBGIS in their classrooms but did not specify participants' names or school names in the data presented.

To address the study's credibility, I used deductive and inductive thematic analysis approaches. In using the deductive thematic analysis, the UTAUT theoretical framework was utilised to identify and interpret patterns of meaning across qualitative data (Clarke & Braun, 2014). The inductive thematic analysis approach was also used to identify and interpret the themes grounded in the data (Braun & Clarke, 2014). The conclusions were only drawn for the study participants, and the findings were not generalised to other contexts (Bertram & Christiansen, 2014). I also used peer debriefing and member checking (Maree, 2007), and support was solicited from colleagues to check the interpretation of the data (critical peer checks) (Rule & John, 2011).

The research participants were also requested to verify the accuracy of what had been reported about them (Rule & John, 2011). The interview protocol was helpful and reduced inconsistency and unintended unfairness. Creswell (2009) stated that the interview protocol establishes a standard procedure to be followed by both the researcher (interviewer) and participants (interviewees). The subjectivity of the researcher in the research process was acknowledged. Subjectivity is based on personal opinions, interpretations, points of view, feelings, and judgement (Bertram & Christiansen, 2014). The audio-recording device was used during the interview for the validity of data generation since this enabled greater accuracy of transcripts (Bertram & Christiansen, 2014).

FINDINGS AND DISCUSSION

Inadequate Teacher Training

The lack of proper teacher training for geography teachers seems to be a major impediment to implementing PBGIS in rural learning ecologies. The responses of Duncan, and Mario reveal that they were never taught GIS at the secondary school. Duncan, and Mario admitted to having been exposed to GIS at the tertiary level, although it was difficult for them since they were not introduced to it in secondary school.

Duncan noted that when he matriculated in 2004, the DBE was still preparing for GIS implementation in secondary schools. Duncan also revealed that although he studied GIS at the university, he was introduced to GIS under the Bachelor of Science (BSc) course and it was different from the GIS he was expected to teach at the secondary school. Duncan (semi-structured interview) expounds:

> *"I am a very old man. Back then when I was still in school there was no GIS. So, I was never taught GIS. I only heard about GIS when I started working here. I completed my*

matric in 2004 and the department of education was still pregnant with GIS. At tertiary level I only did GIS in BSc, but it is very different from this GIS."

Furthermore, Duncan adds that the DBE is not doing enough to train geography teachers to improve GIS implementation in schools. Duncan (semi-structured interview) explains:

"The department of education is doing something in staff developing teachers through workshops, but it is not enough. That is the problem now because they would be taking teachers to workshops where we are taught about GIS and how to interact with GIS but that is not enough because…problem lies on when we trying to teach the learners. I think for the department their hands are also tight…but they are trying to give us some literature we can study."

In a similar way to Duncan, Mario also matriculated in 2007. As a result, he was not introduced to GIS at the secondary school level. However, Mario claims that GIS was taught to him in detail at the university level. Mario (semi-structured interview) expounds:

"I was not taught GIS at secondary school. I matriculated in 2007 and GIS was not there in matric by this time. I think it arrived in 2008. The time I was exposed to GIS it is when I went to university. During my second year at the university…, I did an introduction to GIS, and it was taught in detail."

Mario further outlined that the DBE coordinated workshops in which GIS was taught. However, in recent years, the department complained about a lack of funds. As a result, schools are experiencing challenges in implementing PBGIS. Mario (semi-structured interview) explains:

"Previously, the Department of Education use to give us workshops, but now the department keeps on saying it does not have money to conduct workshops…they must give us workshops so that we can teach our learners GIS properly."

From the above extracts, it is apparent that one of the PBGIS challenges for geography teachers in rural learning ecologies is the lack of proper teacher training. This finding resonates with the sentiments of Mzuza and Westhuizen (2019); they point out that the low intake of trainees/ students at the tertiary level results in a limited number of GIS-qualified teachers, which in turn results in GIS not being taught widely in schools. Furthermore, many teachers do not have the necessary GIS skills and experience due to a lack of in-service training and rapid technological changes. Ayorekire and Twinomuhangi (2012) and Musakwa (2018) also corroborate this finding and point out that the unavailability of teachers experienced enough to teach GIS is a common problem in Africa. The training process helps geography teachers in ensuring that they have a team of teachers that is effective at their work. This is supported by Mzuza and Westhuizen (2019) who attest that geography teachers with excellent GIS training are likely to produce quality work in GIS implementation.

Resources required for PBGIS implementation

This study found that geography teachers are unsure about the resources required to implement PBGIS. Both participants were hesitant to provide straight answers to this question in their semi-structured interviews. However, it was evident from all the responses that topographic and orthophoto maps were perceived as dominant resources required for implementing a PBGIS lesson. Duncan revealed that the required resources include maps, transparencies, and pencils. He further stated that separate maps should be used to engage learners in classroom activities to help them prepare for the examination. However, Duncan lamented that resources are not always provided in the school he teaches because of the lack of funds. Duncan (semi-structured interview) made the following comment:

> *"We should have maps because you cannot do anything in paper two without maps to practice. Have additional maps where learners can draw and do other tasks when given activities. We also need transparencies, and pencils. At times you find that a teacher is asking for resources in a school only to find out that the school cannot afford to buy them and then as a teacher you end up saying let me just leave it."*

Like Duncan, Mario expressed that the necessary resources for PBGIS implementation are transparencies and maps. He added that soft pens and overhead projectors are other useful tools for applying PBGIS skills during teaching and learning. Mario (semi-structured interview) articulates:

> *"There must be some transparencies and maps. A school should own an overhead projector so that data overlaying can be done using transparencies and overhead projectors. Soft pens are also required to draw lines, points, and polygon on the transparencies."*

Mario revealed, however, that in the rural learning ecology he teaches, there is a lack of many PBGIS resources, such as overhead projectors and transparencies. He only employs topographic and orthophoto maps when teaching. Mario (semi-structured interview) echoes:

> *"My school does not have some of the resources like an overhead projector and transparencies. In my school, we teach learners using the orthophoto and topographic maps. I use orthophoto maps to tell my learners that this refers to a raster data then topographic map refers to a vector data. Then I give a reason as to why I am saying so. But it is hard to teach because our school does not have the necessary resources."*

From the above excerpts, we have discovered that topographic and orthophoto maps are dominating resources required for implementing PBGIS although all participants also mention additional resources. The additional resources mentioned by participants are transparencies, pencils, soft pens, computers, and overhead projectors. This is consistent with Antwi et al. (2018), who point out that a classroom should be furnished with some ICT facilities such as computers, projectors, and smartboards that are needed daily. Furthermore, in the same way as participants, Buabeng-Andoh and Yidana (2015) note that a PBGIS task, such as searching for the best location to evacuate residents in the event of a flood, can be completed with the aid of maps, crayons, and tracing paper.

The participants also revealed that the DBE only provides maps to be utilised in the grade 12 examination, and after the exam is completed, the teachers take the same maps and utilise them to teach map work in Grades 10 to 12. This means there can be a shortage of maps since they only accommodate the total number of learners who write the geography examination without considering that the same maps will be used to teach map work to other learners. Therefore, this means that the school must buy additional maps should there be any shortages. According to Amosun (2016), the inequality of educational materials and resources, including the shortage of maps, textbooks, computers, and other information technologies in schools, is a major educational problem in South Africa. This is a challenge when teachers have to implement PBGIS in rural learning ecologies.

Lack of teaching time

The lack of teaching time seems to be another challenge hampering the implementation of PBGIS in a rural learning ecology. Duncan and Mario believe that PBGIS is not given enough time in schools. Duncan revealed that learners in rural learning ecologies struggle in many ways when taught PBGIS due to the lack of resources used in GIS and not having English as their mother tongue. Duncan (semi-structured interview) articulates:

> *"…GIS is a challenge because you will spend more time busy trying to explain to learners. Whilst I think those teachers who are in urban area schools maybe they will spend less time just explaining and going through. But I will have to take a whole hour trying to explain what hardware is, what a scanner is, so that why it is more challenging."*

Similarly, Mario expresses a lack of PBGIS teaching time and further echoes that geography teachers usually teach PBGIS in a rush when examinations are about to be written. As a result, learners are exposed to very limited GIS information. This causes learners to be only introduced to a summary of what there is in the actual GIS. Mario (semi-structured interview) echoes:

> *"GIS is not given enough time. We teach GIS only when learners are about to write the exam. We teach, rushing through, without teaching properly and allowing more time to learners…The learners are only given an introduction or a summary of what is there in the actual GIS…So, it is not given that much time it is supposed to be given. If possible, it is important for the department of education with the department of geography to introduce a GIS subject in schools so that learners can be given more time to explore more on GIS."*

The excerpts above show that sufficient time is key to implementing PBGIS in rural learning ecologies. This finding resonates with Fleischmann and Westhuizen (2015), who point out that time is significant for many reasons in GIS, such as the time required for teachers to attend professional development (PD) workshops to learn the necessary GIS software; the time required to develop or modify instructional materials supported by GIS; as well as the time required in the curriculum of geography subject to effectively teach learners about the technology. Tarisayi (2018) explains that time constraints in teaching of GIS in South Africa stem from the CAPS allocation of only four hours per week to teaching geography. It can be argued, as a result, that geography is viewed as an elective in the CAPS curriculum since it has been allocated inadequate time.

The teaching of GIS becomes theoretical without any exposure to GIS's technical and practical aspects, which is more time-consuming. Furthermore, time constraints also affect staff development as geography teachers lack time to attend GIS workshops and training (Breetzke et al., 2011). Thus, the implementation of PBGIS requires more time than that allocated by DBE in the CAPS curriculum for geography. Adequate time ensure teachers and learners accept and implement PBGIS in the rural learning ecology.

Complex PBGIS concepts

The complexity of PBGIS concepts stood out in certain geography teachers' interviews as one of the obstacles to implementing PBGIS in rural learning ecologies. The responses of Duncan and Mario show that this complexity results from learners who utilise English as their first additional language and not their mother tongue. Duncan noted that the PBGIS concepts are difficult for the learners to understand. He states that PBGIS requires someone with a better understanding of English to grasp the PBGIS concepts easily. He further explained that he spends more time describing the PBGIS concepts so that his learners understand because they are English second-speaking learners. Duncan (semi-structured interview) expounds:

> *"… The complexity of GIS concepts needs learners who have a better understanding of English as a language…you will spend more time busy trying to explain to learners."*

Similarly, to Duncan, Mario also viewed PBGIS concepts as challenging to his learners. Although Mario understands that the language barrier causes the complexity of concepts as a challenge, he further revealed that this impediment is made worse by the fact that the learners do not take mathematics and physics, which at times incorporate some of the same concepts used in GIS. Therefore, it becomes even more difficult for learners because they only hear about these concepts in the geography curriculum. Mario (semi-structured interview) expounds:

> *"…if you look at GIS even though we are basing our teaching on PBGIS, there are a lot of concepts learners have to understand for them to have a broader understanding of GIS. My learners are only doing life sciences, agriculture, and maths literacy so they find it very challenging because most GIS concepts are taken from what would have been done in mathematics and physics studies."*

From the extracts above, we learn that language is another issue impending learners' understanding because of the complexity of PBGIS concepts in rural learning ecologies. Drawing from the literature, Hlalele (2014) notes that a rural learning ecology consists of learners who speak English as their first additional language because it is not their mother tongue. Therefore, PBGIS concepts may be complex to such learners. Resultantly, learners in rural learning ecologies may not understand and accept PBGIS. It is also evident that misunderstanding may be worsened if subjects are not integrated. This is because learners tend to learn about PBGIS concepts for the first time in geography subjects. After all, they are not utilised in other subjects that they normally study.

Improper PBGIS examination paper setting

Duncan and Mario lamented that they are not happy with the way GIS part is set in paper two. Both participants pointed out that the examiners do not provide teachers with proper guidance regard how the part will be assessed. Mario added that GIS is allocated little marks in papers, and this should also be looked at. On the other hand, Duncan further complained about the complexity in the level of questioning, stating that examiners ask more practical questions. I contrast, he perceives questioning as something that is supposed to be textbook-based due to the lack of resources in rural learning ecologies. Duncan (semi-structured interview) comments:

> *"… and also, the problem is with the guys in the exam section. When they set questions, they are different from those we teach. They are more practical, whilst they are supposed to be asking questions that are more textbook based because they have the understanding that the level of technology in our schools is not the same."*

Duncan reveals that the approach examiners use in setting PBGIS in examinations often causes learners to obtain lower marks in this section compared with any other section. He further commented that in the past, GIS questioning was simpler than it has been recently. Therefore, he perceived PBGIS as requiring a good understanding of English for learners to answer questions successfully. Duncan (semi-structured interview) laments:

> *"Hence, you will find that learners in paper two, learners pass question 1, 2, and 3, but when it comes to question 4, which is GIS now learners are failing. So, one thing is that when we started GIS it was simpler, the level of question was fine. In terms of level one, learners were able to try answering but now even level one is more complex you need learners who have a better understanding of English as a language."*

Again, Duncan advised that guidance provision by examiners is crucial considering that rural learning ecologies are doing the curriculum that includes PBGIS. Duncan (semi-structured interview) advises:

> *"… When they included GIS, they were supposed to provide specified guidelines to say these are the type of questions that I might ask GIS is not like geography that had been there for many years. They were supposed to give us the scope that says these are the questions we are going to be asking from taking into account that these learners are disadvantaged in terms of the technology and language."*

Similarly, Mario advised that examiners should seek assistance from ESRI South Africa on structuring GIS questions. Mario also viewed guidance from examiners to geography teachers as crucial regarding how the GIS questions will be structured. Mario also revealed that marks allocated for GIS questions are not adequate: Marion (semi-structured interview) laments:

> *"The questions are not asking learners more. When the map work papers are set, in March, GIS only covers 5 marks, 15 marks in June, 15 marks in September, and 15 marks in the final examination. I am also not happy with the structuring of questions because what we teach in class is not normally asked in question papers. They ask very little from*

what we taught learners in class. Maybe if the examiner could ask for guidance from ESRI South Africa on how to structure questions, it could assist."

From the above excerpts, we are learning that these teachers need proper guidance from examiners regarding how PBGIS questions will be set. According to the participants, this is because examiners tend to be more practical, whereas geography teachers in rural learning ecologies rely mainly on the textbook in teaching GIS. Breetzke et al. (2011), Eksteen et al. (2012), and Mzuza and Westhuizen (2019) confirm that one of the problems identified in South Africa relates to inadequate practical experience in the use of GIS by teachers. Also, PBGIS is not allocated sufficient marks when tested in question papers. Therefore, Mario advised that the examiner should approach ESRI for assistance as they are experts in the field of GIS. According to Breetzke et al. (2011) and Eksteen et al. (2012), PBGIS was introduced by ESRI South Africa for resource-poor schools. For this reason, ESRI South Africa would be in a better position to advise examiners on how to structure questions and focus more on GIS when setting question papers.

RECOMMENDATIONS AND CONCLUSIONS

This study established that the implementation of PBGIS in a rural learning ecology is affected by inadequate teacher training, and resources required for PBGIS implementation. This subsequently presents a challenge for geography teachers in implementing of PBGIS in a rural learning ecology. The study recommends that the DBE, in association with universities, should provide formal training to teachers and provide them with the necessary resources across all schools to ensure the effective teaching of PBGIS. The training may be rendered in the form of prolonged workshops that focus on PBGIS implementation in schools. The DBE may also allocate funds for resources required for PBGIS implementation. The DBE workshops aiming at supporting teachers with PBGIS implementation should include strategies that would enable teachers to simplify the complexity of GIS concepts taught to learners in a rural learning ecology.

This study also concluded that geography teachers had inadequate teaching time to teach PBGIS effectively. The study, therefore, recommends that the DBE provides support to geography teachers by reviewing the time allocated in the Annual Teaching Plan (ATP) for teaching PBGIS in schools.

This study also discovered an issue with complex PBGIS concepts, and improper PBGIS examination settings. I recommend that through workshops, DBE should engage teachers on ways they can implement to simplify the PBGIS concepts to learners for effective teaching and learning of GIS. PBGIS examiners should also provide workshops for teachers to guide on the approach that must be used when teaching PBGIS that will correspond with the way questions are asked in the examination.

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